44th Annual Gun & Missile Systems Conference & Exhibition

"Shaping the Future in Weapon System Development, Deployment, and Reset"

Kansas City, MO

6 - 9 April 2009

Agenda

Monday, 6 April 2009

TRAINING SESSION B - ATLANTA BALLROOM
Changes in DoD 5000, Ms. Karen Byrd, Defense Acquisition University

Tuesday, 7 April 2009

KEYNOTE ADDRESS:
Mr. Chris Deegan, Executive Director, Integrated Warfare Systems, PEO IWS

KEYNOTE ADDRESS:
Mr. Darren McConnell, Director, Systems Engineering & Integration, Redstone Arsenal

GENERAL SESSION - "REQUIREMENTS AND PROGRAM TRENDS"

- Definition of CEP and the Warfighter Benefits of Precision, Mr. Jim Rodrigue, Raytheon Missile Systems
- Design Tools to Reduce Development and Deployment, Mr. Bernard Halls, MSAIC NATO
- Demilitarization as a Systems Engineering Requirement, Mr. Gary Mescavage, U.S. Army ARDEC - Picatinny
- Design for Demil Efforts at GD-OTS, Mr. David Grymonpre, General Dynamics - OTS
- PEO-AMMO PD Non-standard Ammo Initiative, Mr. William Sanville

ATLANTA BALLROOM - EMERGING TECHNOLOGIES

- Large Caliber Gun Assembly Safety Certification – US Approach, Mr. David Smith, U.S. Army RDECOM Benet Laboratories
- Rarefaction Wave Gun Tank Main Armament Demonstrator, Mr. Erick Kathe, ARDEC Benet Labs
- 7938 - Technology Innovations Realized in the M150/M151 Dismounted Fire Control System Development, Mr. Ralph Tillinghast, U.S. Army ARDEC - Picatinny
- 7772 - Development of a Projectile Muzzle Exit Sensor, Mr. Don Levin, Aberdeen Test Center
- 7917 - Advances in High Performance, Non-Metallic Engineering Materials, Mr. Victor C.F. Hillyard, Ensinger, Inc

NEW YORK BALLROOM - ENERGETICS

- Marine Corps Total Life Cycle Management Value Stream Deployment, Mr. Gale Heaivilin
- 7885 - Novel Techniques for Improved Munitions Development, Mr. Gert J.H.G Scholtes, TNO Defence, Security and Safety
- 7781 - High Density, Multi-Granulation, Propelling Charge Design, Mr. Robert Pulver, General Dynamics-OTS
- 7782 - ECL® Propellant Demonstration of Extended Range in 120mm Mortar Combined with Ballistic and Chemical Stability Equals Win for the Warfighter, Mr. Howard Shimm, U.S. Army ARDEC - Picatinny
- 7925 - Advanced Celluloid Technology for the 120mm Mortar Propelling Charges, Mr. Brian Talley, U.S. Army ARDEC - Picatinny
- 7924 - Environmentally Friendly 120mm LED Tank Ammunition Tracer, Mr. John Kostka, U.S. Army ARDEC - Picatinny
- 7858 - Highly Energetic Materials Incorporated into New Warhead Designs, Dr. Charles Kline, Kline Technical Consulting, LLC
- 7784 - Processing of Aluminum-Based Nanothermites in a Circulating Mixer, Dr. Jacek Swiatkiewicz, Innovative Materials and Processes, LLC
- 7759 - Gun Propellant For The 27mm Cal. Gun Eurofighter Jet, Mr. Dietmar Mueller, Fraunhofer Institut Chemische Technologies
- 7783 - Improved LW30 Ammunition via Ballistic and Chemical Stability of ECL® Propellant and Improved Ignition System, Ms. Kelly Moran, Alliant Techsystems, Inc.

Wednesday, 8 April 2009

ATLANTA BALLROOM - EMERGING TECHNOLOGIES

- 7819 - The Combustion Light Gas Gun - A Progress Update, Mr. David Kruczynski, UTRON, Inc.
- 7972 - A New Method for Fabricating Copper Rotating Bands on Munitions, Mr. Michael Minnicino, Aberdeen Proving Ground

ATLANTA BALLROOM - AMMUNITION

- 7741 - Super 40mm High Explosive Air Burst - Shaping the Future, Mrs. Kara Sims, General Dynamics - OTS
- 7742 - 30x113mm Target Practice Spotter Cartridge - Shaping the Future, Mr. Paul Reynolds, General Dynamics - OTS
- 7743 - 30x113mm Programmable Air Burst Munitions - Shaping the Future, Mr. Paul Reynolds, General Dynamics - OTS
- 7921 - HERO Compliant Electric Primer for Tank Ammunition, Mr. Jason Mishock, U.S. Army ARDEC - Picatinny
- 7922 - Warhead Development for the Long Range Land Attack Projectile, Mr. Tyrus Burford, General Dynamics - OTS

ATLANTA BALLROOM - PRECISION WEAPONS

- 7713 - Issues to be Considered in Collateral Damage with Projectiles, Mr. Chris Geswender, Raytheon Missile Systems
- 7949 - Joint Development of a Non-Magnetic Azimuth Sensor for Dismounted Targeting Operations in All Environments, Ms. Kate Jones, NSWC/Dahlgren
- 7856 - Control of a Fin Stabilized High Spinning Projectile, Mr. Rabin Shalil, MalaM, IAI, Israel
- 7895 - BTERM II Projectile, Mr. Mike Lukas, Naval Surface Warfare Center/Dahlgren Division

NEW YORK BALLROOM - ENERGETICS

- 7754 - Reactive Material Ignition, Output & Explosive Neutralization Assessment, Mr. Steven Kim, NSWC Indian Head
- 7863 - Consolidation of 105mm Artillery M67/M200 into Single Charge System, Ms. Kelly Moran, Alliant Techsystems, Inc.

NEW YORK BALLROOM - TACTICAL ROCKETS & MISSILES

- 7946 - Adaptive Flight Control Surfaces: Revolutionizing Missile and Munition Flight Control Systems, Professor Ronald Barrett, University of Kansas, Aerospace Engineering Department
- 7738 - IM Explosive for SMAW HEAA Warhead, Ms. Nancy Johnson, NSWC Indian Head
- Rocket Trainer, Nammo Talley
- AARGM, Alliant Techsystems, Inc.
- 7919 - Development and Fielding of the Guided Multi-Launch Rocket System (GMRLS) Unitary Warhead, Ms. Renita Friese, General Dynamics - OTS
- 7948 - Hovering Missiles: New Tools for Target ID, Interior Precision Strike, Friendly Fire Mitigations and Persistent Suppression, Professor Ronald Barrett, University of Kansas, Aerospace Engineering Department
- 7943 - ETF (Electronics Test Fuze) - A Flight Platform for Test and Evaluation of Water Piercing Missile Launcher (WPML) Systems, Mr. Michael Irwin, NSWC/ Dahlgren

NEW YORK BALLROOM - PLATFORMS & WEAPON SYSTEMS INTEGRATION

- 7775 - Paladin Armament Upgrade through Integration of NDI Technology, Mr. Peter Henry, BAE Systems
- Mk-45 Stabilized Gun System, Mr. Steve Cannon, NSWC

Thursday, 9 April 2009

ATLANTA BALLROOM - PRECISION WEAPONS

- 7876 - Precision Guidance Kit (PGK) System Development and Demonstration (SDD) Status Update, Mr. Doug Storsved, ATK Advanced Weapons
- 7937 - Precision Urban Mortar Attack, Mr. Bryan Freeman, NSWC/Dahlgren
- 7793 - Flight Control 81mm Mortar, Mr. Sanford Steelman III, NSWC/Dahlgren

ATLANTA BALLROOM - PLATFORMS & WEAPON SYSTEMS INTEGRATION

- 7744 - Warship Upgrades to Utilize Modern Standard Missile, Mr. Newell (Butch) Young, Raytheon Missile Systems
- 7914 - Qualification Testing of High Rate of Fire Gun Systems, Mr. David Maher, General Dynamics Armament and Technical Products
- 7961 - 40mm Cased Telescoped Weapon System Comes to Maturity Advancing the State of the Art, Mr. David Leslie, BAE Systems
- 155mm Third Generation Maritime Fire Support (TMF), Mr. Rob McClure

NEW YORK BALLROOM - EFFECTIVENESS

- 7839 - Driving Affordable Common Solutions with Mission Analysis, Mr. Andrew Hinsdale, Raytheon Missile Systems
- 8151 - 25mm Ammunition Development for the JSF, Mr. Martin van de Voorde, TNO Defence, Security and Safety
- 7906 - Trajectory Matching Procedure/Practice for a Guided Projectile using MATLAB/Simulink, Ms. Yin Chen, U.S. Army ARDEC - Picatinny
- 7970 - A Numerical Method to Predict the Spin Behavior of Despun Munitions, Mr. Michael Minnicino, Aberdeen Proving Grounds
- 7745 - Evolving Artillery Operational Concepts from Guided Projectiles, Mr. Chris Geswender, Raytheon Missile Systems
- 7810 - Trajectory Simulation of the Ejected Vent Plugs during Premature Fuze Detonation of the 81mm, M879 Full Range Practice Mortar Cartridge, Mr. Seungeuk Han, U.S. Army RDECOM-ARDEC
- 7912 - Modeling and Simulation Advances in Large Caliber Muzzle Brake Development, Mr. Daniel Cler, U.S. Army

RDECOM/ARDEC/WSEC/Benet Laboratories

- 7923 - Effectiveness of ABM, Mr. Pascal Paulissen, TNO Defence, Security and Safety
- 7915 - A Different Approach to Determining Weapon System Caliber, Mr. Mohan Palathingal, U.S. Army ARDEC - Picatinny

NDIA
National Defense Industrial Association

PROMOTING NATIONAL SECURITY SINCE 1919

44th ANNUAL GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

"Shaping The Future in Weapon System Development, Deployment, and Reset"

APRIL 6-9, 2009
WWW.NDIA.ORG/MEETINGS/9590

HYATT REGENCY CROWN CENTER ▸ KANSAS CITY, MO

EVENT #9590

44TH ANNUAL GUN & MISSILE SYSTEMS CONFERENCE & EXHIBITION

APRIL 6-9, 2009 ▸ KANSAS CITY, MO

The 44th Annual NDIA Armament Systems: Gun and Missile Systems Conference and Exhibition will address the theme, "Shaping The Future in Weapon System Development, Deployment, and Reset." The conference will provide a forum for discussing methods to enhance defense-related capabilities—not only through available technology, but also through development of personnel. A broad range of topics related to design and development of technology and training, and development of people in the gun and missile system industry will be presented.

The full scope of gun and missile tactical weaponry and related components will be discussed including: direct/indirect/precision fire systems, tactical rockets and missiles, energetics, effectiveness, modeling and simulation, platform integration and emerging technologies. Representatives of the U.S. and international defense communities, including both government and industry members are invited to participate.

GUN & MISSILE SYSTEMS LEADERSHIP

Armaments Division Chair: Mr. David Broden, *Broden Resource Solutions, LLC*

Gun & Missile Committee Chair: Mr. Brian Tasson, *Alliant Techsystems, Inc.*

Conference Chairman: Mr. Scott Martin, *Raytheon*

Conference Co-Chairs: Mr. Robert Glantz, *Alliant Techsystems, Inc.;* Mr. Greg Hill, *Meggitt Defense Systems*

GUN & MISSILE SYSTEMS SESSION CHAIRS

Requirements and Program Trends: Mr. Matthew Diehl, *General Dynamics-ATP*; Mr. James Ripley, *United States Marine Corps*

Emerging Technologies: Mr. Robert Glantz, *Alliant Techsystems, Inc.*; Mr. Michael Till, *NSWC/Dahlgren*

Energetics: Mr. Joseph Buzzett, *General Dynamics - OTS;* Mr. Michael Thornton, *NSWC/ Indian Head*

Ammunition: Mr. Matt Solverson, *General Dynamics - OTS;* Mr. Charles Cording, *U.S. Army, PM, MAS*

Tactical Rockets & Missiles: Mr. Ed De Pasquale, *Nammo Talley;* Mr. Anthony Gabriele, *RDECOM-ARDEC Benet Labs*

Precision Weapons: Mr. Enrico Mutascio, *Esterline Defense Group*; Mr. James Talley, *General Dynamics-ATP*

Platforms & Weapon Systems Integration: Mr. Steven French, *BAE Systems*; Mr. CJ Toombs, *NAVAIR-WD, China Lake*

Effectiveness: Mr. Greg Hill, *Meggitt Defense Systems;* Mr. Steven Piper, *Pacific Coast International*

GENERAL CONFERENCE INFORMATION:

During conference registration and check in, each participant will be issued an identification badge. Please be prepared to present picture ID. Badges must be worn at all conference functions.

Proceedings will be available on the web one to two weeks after the conference through the Defense Technical Information Center (DTIC). You will receive notification via email that proceedings are posted and available.

Appropriate dress for this conference is business casual for civilians and Class B uniform or uniform of the day for military.

MONDAY, APRIL 6

10:00 am - 3:00 pm	**EXHIBITOR MOVE-IN**
12:00 pm - 5:00 pm	**REGISTRATION**
2:00 pm - 3:00 pm	**TRAINING SESSION A - ATLANTA BALLROOM** Lessons Learned in EVM Control Account Analysis and Design, *Mr. Thomas Cowles, Raytheon Space and Airborne Systems*
3:00 pm - 4:00 pm	**TRAINING SESSION B - ATLANTA BALLROOM** Changes in DoD 5000, *Ms. Karen Byrd, Defense Acquisition University*
5:00 pm - 6:00 pm	**EXHIBIT HALL OPEN & WELCOME RECEPTION**

TUESDAY, APRIL 7

7:00 am - 5:00 pm	**REGISTRATION**
7:00 am - 8:00 am	**CONTINENTAL BREAKFAST IN FOYER**
8:00 am - 8:15 am	**WELCOMING REMARKS & CONFERENCE OVERVIEW** Mr. Bob Glantz, *NDIA Conference Co-Chair; Alliant Techsystems, Inc.* Mr. Brian Tasson*, NDIA Gun & Missile Chairman; Alliant Techsystems, Inc.*
8:15 am - 8:20 am	**NDIA 2010 GUN & MISSILE/SMALL ARMS JOINT SYMPOSIUM** Mr. Greg Hill, *2010 NDIA Conference Chair; Meggitt Defense Systems*
8:20 am - 8:30 am	**NDIA ARMAMENTS DIVISION UPDATE** Mr. Dave Broden, *NDIA Armaments Division Chair; Broden Resource Solutions*
8:30 am - 9:00 am	**KEYNOTE ADDRESS:** Mr. Chris Deegan, *Executive Director*, *Integrated Warfare Systems, PEO IWS*
9:00 am - 9:30 am	**KEYNOTE ADDRESS:** Mr. Darren McConnell, *Director, Systems Engineering & Integration, Redstone Arsenal*
9:30 am - 10:00 am	**BREAK IN EXHIBIT HALL**
10:00 am - 12:25 pm	**GENERAL SESSION - "REQUIREMENTS AND PROGRAM TRENDS"**
10:00 am - 10:20 am	Definition of CEP and the Warfighter Benefits of Precision, *Mr. Jim Rodrigue, Raytheon Missile Systems*
10:20 am - 10:40 am	Design Tools to Reduce Development and Deployment*, Mr. Bernard Halls, MSAIC NATO*
10:40 am - 11:00 am	Demilitarization as a Systems Engineering Requirement*, Mr. Gary Mescavage, U.S. Army ARDEC - Picatinny*
11:00 am - 11:20 am	Design for Demil Efforts at GD-OTS, *Mr. David Grymonpre, General Dynamics - OTS*
11:20 am - 12:05 pm	Panel Discussion - Demilitarization*, U.S. Army*
12:05 pm - 12:25 pm	PEO-AMMO PD Non-standard Ammo Initiative, *Mr. William Sanville*
12:25 pm - 1:25 pm	**LUNCH IN PERSHING HALL**

1:25 pm - 5:10 pm **CONCURRENT SESSIONS**

ATLANTA BALLROOM

EMERGING TECHNOLOGIES

1:30 pm - 1:50 pm Large Caliber Gun Assembly Safety Certification – US Approach, *Mr. David Smith, U.S. Army RDECOM Benet Laboratories*

1:50 pm - 2:10 pm 7787 - Revolutionary Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination (RIGHTTRAC) Technology Demonstrator Program, *Mr. Patrick Brousseau, DRDC Valcartier*

2:10 pm - 2:30 pm 77863 - Flowform, Lightweight Machine Gun Barrel, *Mr. Matthew Fonte, Dynamic Flowform Corp.*

2:30 pm - 2:50 pm 7899 - Optical Communication, Powering and Data Transfer Technology to Eliminate Internal Wirings and Umbilical Cords, *Dr. Jahangir Rastegar, Omnitek Partners, LLC*

2:50 pm - 3:30 pm **BREAK IN EXHIBIT HALL**

3:30 pm - 3:50 pm Rarefaction Wave Gun Tank Main Armament Demonstrator, *Mr. Erick Kathe, ARDEC Benet Labs*

3:50 pm - 4:10 pm 7938 - Technology Innovations Realized in the M150/M151 Dismounted Fire Control System Development, *Mr. Ralph Tillinghast, U.S. Army ARDEC - Picatinny*

4:10 pm - 4:30 pm 7772 - Development of a Projectile Muzzle Exit Sensor, *Mr. Don Levin, Aberdeen Test Center*

4:30 pm - 4:50 pm 7917 - Advances in High Performance, Non-Metallic Engineering Materials, *Mr. Victor C.F. Hillyard, Ensinger, Inc.*

NEW YORK BALLROOM

ENERGETICS

1:30 pm - 1:50 pm Marine Corps Total Life Cycle Managment Value Stream Deployment, *Mr. Gale Heaivilin*

1:50 pm - 2:10 pm 7885 - Novel Techniques for Improved Munitions Development, *Mr. Gert J.H.G Scholtes, TNO Defence, Security and Safety*

2:10 pm - 2:30 pm 7781 - High Density, Multi-Granulation, Propelling Charge Design, *Mr. Robert Pulver, General Dynamics-OTS*

2:30 pm - 2:50 pm 7782 - ECL® Propellant Demonstration of Extended Range in 120mm Mortar Combined with Ballistic and Chemical Stability Equals Win for the Warfighter, *Mr. Howard Shimm, U.S. Army ARDEC - Picatinny*

2:50 pm - 3:10 pm 7925 - Advanced Celluloid Technology for the 120mm Mortar Propelling Charges, *Mr. Brian Talley, U.S. Army ARDEC - Picatinny*

3:30 pm - 3:50 pm 7924 - Environmentally Friendly 120mm LED Tank Ammunition Tracer, *Mr. John Kostka, U.S. Army ARDEC - Picatinny*

3:50 pm - 4:10 pm 7858 - Highly Energetic Materials Incorporated into New Warhead Designs, *Dr. Charles Kline, Kline Technical Consulting, LLC*

4:10 pm - 4:30 pm 7784 - Processing of Aluminum-Based Nanothermites in a Circulating Mixer, *Dr. Jacek Swiatkiewicz, Innovative Materials and Processes, LLC*

4:30 pm - 4:50 pm 7759 - Gun Propellant For The 27mm Cal. Gun Eurofighter Jet, *Mr. Dietmar Mueller, Fraunhofer Institut Chemische Technologies*

4:50 pm - 5:10 pm 7783 - Improved LW30 Ammunition via Ballistic and Chemical Stability of ECL® Propellant and Improved Ignition System, *Ms. Kelly Moran, Alliant Techsystems, Inc.*

5:10 pm - 6:30 pm **RECEPTION IN EXHIBIT HALL**

WEDNESDAY, APRIL 8

7:00 am - 5:00 pm **REGISTRATION**

7:00 am - 8:00 am **CONTINENTAL BREAKFAST IN FOYER**

8:10 am - 11:50 am **CONCURRENT SESSIONS**

ATLANTA BALLROOM

EMERGING TECHNOLOGIES

8:00 am - 8:20 am 7819 - The Combustion Light Gas Gun - A Progress Update, *Mr. David Kruczynski, UTRON, Inc.*

8:20 am - 8:40 am 7972 - A New Method for Fabricating Copper Rotating Bands on Munitions, *Mr. Michael Minnicino, Aberdeen Proving Ground*

AMMUNITION

8:45 am - 9:05 am 7741 - Super 40mm High Explosive Air Burst - Shaping the Future, *Mrs. Kara Sims, General Dynamics - OTS*

9:05 am - 9:25 am 7742 - 30x113mm Target Practice Spotter Cartridge - Shaping the Future, *Mr. Paul Reynolds, General Dynamics - OTS*

9:25 am - 10:10 am **BREAK IN EXHIBIT HALL**

10:10 am - 10:30 am 7743 - 30x113mm Programmable Air Burst Munitions - Shaping the Future, *Mr. Paul Reynolds, General Dynamics - OTS*

10:30 am - 10:50 am 7921 - HERO Compliant Electric Primer for Tank Ammunition, *Mr. Jason Mishock, U.S. Army ARDEC - Picatinny*

10:50 am - 11:10 am 7922 - Warhead Development for the Long Range Land Attack Projectile, *Mr. Tyrus Burford, General Dynamics - OTS*

11:50 am - 1:15 pm **AWARDS LUNCH**

1:15 pm - 4:00 pm **CONCURRENT SESSIONS**

1:15 pm - 1:35 pm 7794 - Medium Caliber Ammunition, *Dr. Rao Yalamanchili, U.S. Army ARDEC - Picatinny*

1:35 pm - 1:55 pm Lightweight Polymer Cased Ammunition Cartridges, *Mr. Paul McElroy, Temeku Technologies, Inc.*

NEW YORK BALLROOM

ENERGETICS

8:00 am - 8:20 am 7754 - Reactive Material Ignition, Output & Explosive Neutralization Assessment, *Mr. Steven Kim, NSWC Indian Head*

8:20 am - 8:40 am 7863 - Consolidation of 105mm Artillery M67/M200 into Single Charge System, *Ms. Kelly Moran, Alliant Techsystems, Inc.*

TACTICAL ROCKETS & MISSILES

8:45 am - 9:05 am 7946 - Adaptive Flight Control Surfaces: Revolutionizing Missile and Munition Flight Control Systems, *Professor Ronald Barrett, University of Kansas, Aerospace Engineering Department*

9:05 am - 9:25 am Flowforming of Components for Tactical Rockets is both Practical and Economically Feasible, *Mr. Matthew Fonte, Dynamic Flowform Corp.*

10:10 am - 10:30 am Rapid PAn Evaluation of the Fire Appreciation Modelling, *Captain Hakan Gurkan, Turkish Air Force 3rd Air Support Maintenance Center*

10:30 am - 10:50 am 7738 - IM Explosive for SMAW HEAA Warhead, *Ms. Nancy Johnson, NSWC Indian Head*

10:50 am - 11:10 am 7918 - GMLRS Rod Payload, *Ms. Renita Friese, General Dynamics - OTS*

11:10 am - 11:30 am Rocket Trainer, *Nammo Talley*

11:30 am - 11:50 am AARGM, *Alliant Techsystems, Inc.*

1:15 pm - 1:35 pm 7919 - Development and Fielding of the Guided Multi-Launch Rocket System (GMRLS) Unitary Warhead, *Ms. Renita Friese, General Dynamics - OTS*

1:35 pm - 1:55 pm 7948 - Hovering Missiles: New Tools for Target ID, Interior Precision Strike, Friendly Fire Mitigations and Persistent Suppression, *Professor Ronald Barrett, University of Kansas, Aerospace Engineering Department*

1:55 pm - 2:15 pm 7943 - ETF (Electronics Test Fuze) - A Flight Platform for Test and Evaluation of Water Piercing Missile Launcher (WPML) Systems, *Mr. Michael Irwin, NSWC/ Dahlgren*

2:15 pm - 2:35 pm BREAK IN EXHIBIT HALL

2:35 pm - 7:00 pm EXHIBIT HALL CLOSES & EXHIBITOR MOVE-OUT

ATLANTA BALLROOM

PRECISION WEAPONS

2:40 pm - 3:00 pm 7713 - Issues to be Considered in Collateral Damage with Projectiles, *Mr. Chris Geswender, Raytheon Missile Systems*

3:00 pm - 3:20 pm 7949 - Joint Development of a Non-Magnetic Azimuth Sensor for Dismounted Targeting Operations in All Environments, *Ms. Kate Jones, NSWC/Dahlgren*

3:20 pm - 3:40 pm 7856 - Control of a Fin Stabilized High Spinning Projectile, *Mr. Rabin Shalil, MalaM, IAI, Israel*

3:40 pm - 4:00 pm 7895 - BTERM II Projectile, *Mr. Mike Lukas, Naval Surface Warfare Center/ Dahlgren Division*

NEW YORK BALLROOM

PLATFORMS & WEAPON SYSTEMS INTEGRATION

2:40 pm - 3:00 pm 7861 - Integrating Robotic Platforms and Non-Lethals for the Future Warfighter, *Mr. Edward Hackett, EH-Group, Inc.*

3:00 pm - 3:20 pm 7775 - Paladin Armament Upgrade through Integration of NDI Technology, *Mr. Peter Henry, BAE Systems*

3:20 pm - 3:40 pm Mk-45 Stabilized Gun System, *Mr. Steve Cannon, NSWC*

4:00 pm CONFERENCE ADJOURNS FOR THE DAY

THURSDAY, APRIL 9

7:00 am - 12:00 pm REGISTRATION

7:00 am - 8:00 am CONTINENTAL BREAKFAST IN FOYER

8:00 am - 12:20 am CONCURRENT SESSIONS

PRECISION WEAPONS

8:00 am - 8:20 am 7876 - Precision Guidance Kit (PGK) System Development and Demonstration (SDD) Status Update, *Mr. Doug Storsved, ATK Advanced Weapons*

8:20 am - 8:40 am 7937 - Precision Urban Mortar Attack, *Mr. Bryan Freeman, NSWC/Dahlgren*

8:40 am - 9:00 am 7793 - Flight Control 81mm Mortar, *Mr. Sanford Steelman III, NSWC/Dahlgren*

9:00 am - 9:20 am 7729 - EndFire Proximity Sensor, *Mr. Robert Hertlein, L3-KDI Precision Products*

EFFECTIVENESS

8:00 am - 8:20 am 7839 - Driving Affordable Common Solutions with Mission Analysis, *Mr. Andrew Hinsdale, Raytheon Missile Systems*

8:20 am - 8:40 am Simulation-based Development and Optimization of Advanced Gun Weapon Systems, *Mr. Dave Cooper, BAE Systems*

8:40 am - 9:00 am 8151 - 25mm Ammunition Development for the JSF, *Mr. Martin van de Voorde, TNO Defence, Security and Safety*

9:00 am - 9:20 am Simulation-Based, Effects-Driven CONOPS and Growth Strategy Development, *Mr. Dave Cooper, BAE Systems*

9:20 am - 9:40 am 7906 - Trajectory Matching Procedure/Practice for a Guided Projectile using MATLAB/ Simulink, *Ms. Yin Chen, U.S. Army ARDEC - Picatinny*

10:00 am - 10:20 am **BREAK IN FOYER**

ATLANTA BALLROOM

PLATFORMS & WEAPON SYSTEMS INTEGRATION

10:20 am - 10:40 am 7744 - Warship Upgrades to Utilize Modern Standard Missile, *Mr. Newell (Butch) Young, Raytheon Missile Systems*

10:40 am - 11:00 am 7914 - Qualification Testing of High Rate of Fire Gun Systems, *Mr. David Maher, General Dynamics Armament and Technical Products*

11:00 am - 11:20 am 7961 - 40mm Cased Telescoped Weapon System Comes to Maturity Advancing the State of the Art, *Mr. David Leslie, BAE Systems*

11:20 am - 11:40 am 155mm Third Generation Maritime Fire Support (TMF), *Mr. Rob McClure*

NEW YORK BALLROOM

EFFECTIVENESS

10:20 am - 10:40 am 7970 - A Numerical Method to Predict the Spin Behavior of Despun Munitions, *Mr. Michael Minnicino, Aberdeen Proving Grounds*

10:40 am - 11:00 am 7745 - Evolving Artillery Operational Concepts from Guided Projectiles, *Mr. Chris Geswender, Raytheon Missile Systems*

11:00 am - 11:20 am 7810 - Trajectory Simulation of the Ejected Vent Plugs during Premature Fuze Detonation of the 81mm, M879 Full Range Practice Mortar Cartridge, *Mr. Seungeuk Han, U.S. Army RDECOM-ARDEC*

11:20 am - 11:40 am 7912 - Modeling and Simulation Advances in Large Caliber Muzzle Brake Development, *Mr. Daniel Cler, U.S. Army RDECOM/ARDEC/WSEC/Benet Laboratories*

11:40 am - 12:00 pm 7923 - Effectiveness of ABM, *Mr. Pascal Paulissen, TNO Defence, Security and Safety*

12:00 pm - 12:20 pm 7915 - A Different Approach to Determining Weapon System Caliber, *Mr. Mohan Palathingal, U.S. Army ARDEC - Picatinny*

12:20 pm **CONFERENCE ADJOURNS**

HOTEL PARKING

VALET:

Short term (in & out the same day): $9.00

Overnight: $17.00 - with in/out privileges.

SELF PARKING:

Overnight: $13.50 with in/out privleges.

Banquet Validation: $4.00 (3 hours)

Early Bird (in before 10am & out the same day): $7.00

This hotel cannot accommodate vehicles that are taller than 6'9" (i.e. no motorhomes/tall vans, etc).

AIRPORT INFORMATION

FROM AIRPORT:

KCI Super Shuttle (Hours 5:50am-11:25pm): $17.00 per person - $29.00 round trip per person. Leaves from Baggage Claim area at 5 minutes to the hour and 25 minutes after the hour. Reservations are not required. For additional info, please call KCI Shuttle service at 800-243-6383.

Shuttle Service is wheelchair accessible with chair lifts. (Maroon vans and buses with yellow lettering that say KCI Shuttle.)

TAXI: Approx $35.00-$40.00

DIRECTIONS FROM AIRPORT

From Kansas City International Airport (20 miles): Take I-29 South to U.S. 169 South (169 turns into Broadway). Proceed on Broadway to 20th Street. Turn left (east) and proceed to McGee Street. Turn right onto McGee Street. Hotel is 3 blocks uphill on left.

ADDITIONAL AUTHORS

Abstract ID	Abstract Title	Secondary Authors
7738	IM Explosive for SMAW HEAA Warhead	Mrs. Carrie Gonzalez, Mr. Wayne Reed, Ms. Laura Kowalczyk, Mr. William Myers
7744	Warship Upgrades to Utilize Modern Standard Missile	Mr. Vineet Daga
7745	Evolving Artillery Operational Concepts from Guided Projectiles	Mr. Steve Bennett, Mr. David Brockway
7749	Cluster Munition Demilitarization at GD-OTS	Mr. Wilfried Meyer, Mrs. Carol Sabat
7754	Reactive Material Ignition, Output & Explosive Neutralization Assessment	Mr. Dan Lanterman, Mr. Brian Amato, Mr. Gerry Laib, and Mr. Kendall Elliott
7759	Gun Propellant For The 27 mm Cal. Gun Eurofighter Jet	Dr. Dietmar Mueller, Mr. Walter Langlotz
7772	Development of a Projectile Muzzle Exit Sensor	Mr. Arthur Krenzel, Mr. George Cawrse
7775	Paladin Armament upgrade through integration of NDI technology	Mr. Bart Anderson
7779	Precision Extended Range Munition	Mr. George Barnych, Mr. Patrick Freemyers
7781	High Density, Mult-Granulation, Propelling Charge Design	Mr. Daniel Lapage
7782	ECL® Propellant Demonstration of Extended Range in 120mm Mortar Combined with Ballistic and Chemical Stability Equals Win for the Warfighter	Mr. Howard Shimm, Mr. Dominik Antenen, Mr. Peter Zoss, Dr. Ulrich Schaedeli
7783	Improved LW30 Ammunition via Ballistic and Chemical Stability of ECL® Propellant and Improved Ignition System	Mr. Bishara Elmasri, Mr. Dominik Antenen, Dr. Ulrich Schaedeli, Mr. Howard Shimm
7784	Processing of Aluminum-Based Nanothermites in a Circulating Mixer	Dr. Jacek Swiatkiewicz, Dr. Kelvin Higa
7787	Revolutionary Insensitive, Green and Healthier Training Technology with Reduced Adverse Contamination (RIGHTTRAC) Technology Demonstrator Program	Dr. Sylvie Brochu, Mr. Marc Brassard, Dr. Guy Ampleman, Dr. Sonia Thiboutot
7790	Design for Demil Efforts at GD-OTS	Mrs. Carol Sabat, Mr. Wilfried Meyer
7791	Lightweight Polymer Cased Ammunition Cartrides	Dr. Andrea Hoyt-Haight, Dr. Peter Poulsen, Dr. Ronald Allred, Dr. Jan Gosau
7794	Environmentally Friendly Electric Primers for Medium Caliber Ammunition	Mr. John Hirlinger, Mr. Chris Csernica
7819	The Combustion Light Gas Gun – A Progress Update	Mr. Dennis Massey
7839	Driving Affordable Common Solutions with Mission Analysis	Mr. Daniel Cheeseman, Mr. David Stone
7858	Highly Energetic Materials Incorporated into New Warhead Designs	Dr. Vivek Dave
7861	Integrating Robotic Platforms and Non-Lethals For the Future Warfighter	Ms. Charlotte Hallengren
7863	Consolidation of 105mm Artillery M67/M200 into Single Charge System	Mr. Dominik Antenen, Mr. Michael Ramin, Dr. Ulrich Schaedeli, Mr. Nguyen Tran
7885	Novel techniques for improved munitions development	Mr. Gert Scholtes, Mr. Wim de Klerk, Mr. Chris van Driel, Mr. Martijn Zebregs
7890	Definition of CEP and the Warfighter Benefits for Precision Projectiles	Mr. Jon Peoble

7899	Optical Communication, Powering and Data Transfer Technology to Eliminate Internal Wirings and Umbilical Cords	Mr. Carlos Pereira, Dr. Harbans Dhadwal
7906	Trajectory Matching Procedure/Practice for a Guided Projectile Using MATLAB/ Simulink	Mr. Thomas Recchia
7912	Modeling and Simulation Advances in Large Caliber Muzzle Brake Development	Mr. Robert Carson, Mr. Mark Doxbeck, Mr. Jeffrey Greer, Mr. Mark Witherell
7914	Qualification Testing of High Rate of Fire Gun Systems	Mr. Douglas Parker
7915	A Different Approach to Determining Weapon System Caliber	Mr. Yu Lu, Mr. Mihaly Horvath, Mr. Daniel Vo
7917	Advances in High Performance, Non Metallic Engineering Materials	Ms. Kim Reddick
7918	GMLRS Rod Payload	Mr. Gary Jimmerson
7919	Development and Fielding of the Guided Multi-Launch Rocket System (GMRLS) Unitary Warhead	Ms. Tracey Westmoreland
7921	HERO Compliant Electric Primer for Tank Ammunition	Mr. Jason Mishock
7922	Warhead Development for the Long Range Land Attack Projectile (LRLAP)	Mr. Aaron Warriner
7923	Effectiveness of ABM	Mr. Theo Verhagen, Mr. Eelko van Meerten
7925	Advanced Celluloid Technology	Mr. Howie Shimm, Mr. Peter Bonnett, Mr. Joseph Palk, Mr. Brian Talley
7926	Extended Range Propelling Charge for the 120mm M934A1 Mortar Cartridge	Mr. Howie Shimm, Mr. Mike Kauffman, Mr. Brian Talley, Mr. Peter Bonnett
7927	Design of Experiments Application to M103 Cartridge Case Neck Failure Investigation	Mr. Kurt Schroeder
7938	Technology Innovations Realized in the M150/M151 Dismounted Fire Control System Development	Mr. Amit Makhijani
7943	ETF (Electronics Test Fuze) – A Flight Platform for Test and Evaluation of Water Piercing Missile Launcher (WPML) Systems	Mr. Hamish Malin
7972	A New Method for Fabricating Copper Rotating Bands on Munitions	Dr. Matthew Trexler
8019	EFSS Precision Extended Range Munition	Mr. Patrick Freemyers, Mr. Stephen Driscoll
8151	25 mm Ammunition Development for the JSF	Mr. Eelko van Meerten
8254	Simulation Results of Precision Guided Munition Performance using Precision GPS Ephemeris (PGE) Guidance	Dr. Bruce Johnson, Ms. Yan Lu, Mr. Frank Fresconi

Raytheon

Customer Success Is Our Mission

System Issues to Consider for Reducing Collateral Damage

Chris E. Geswender

David Brockway

April 23, 2009

What Drives Collateral Damage?

- Accuracy
  - Siting
  - Targeting
  - MET quality
  - Mission planning

Crew, Fire Control, MET Support

- Precision
  - Reliability
  - Propellant quality
  - Projectile maneuverability
  - Range/super-elevation influences

Guidance, Architecture

- Lethality
  - Warhead size
  - Fuzing
  - Verticality

Verticality, Warhead, Fuzing

MET — Meteorological

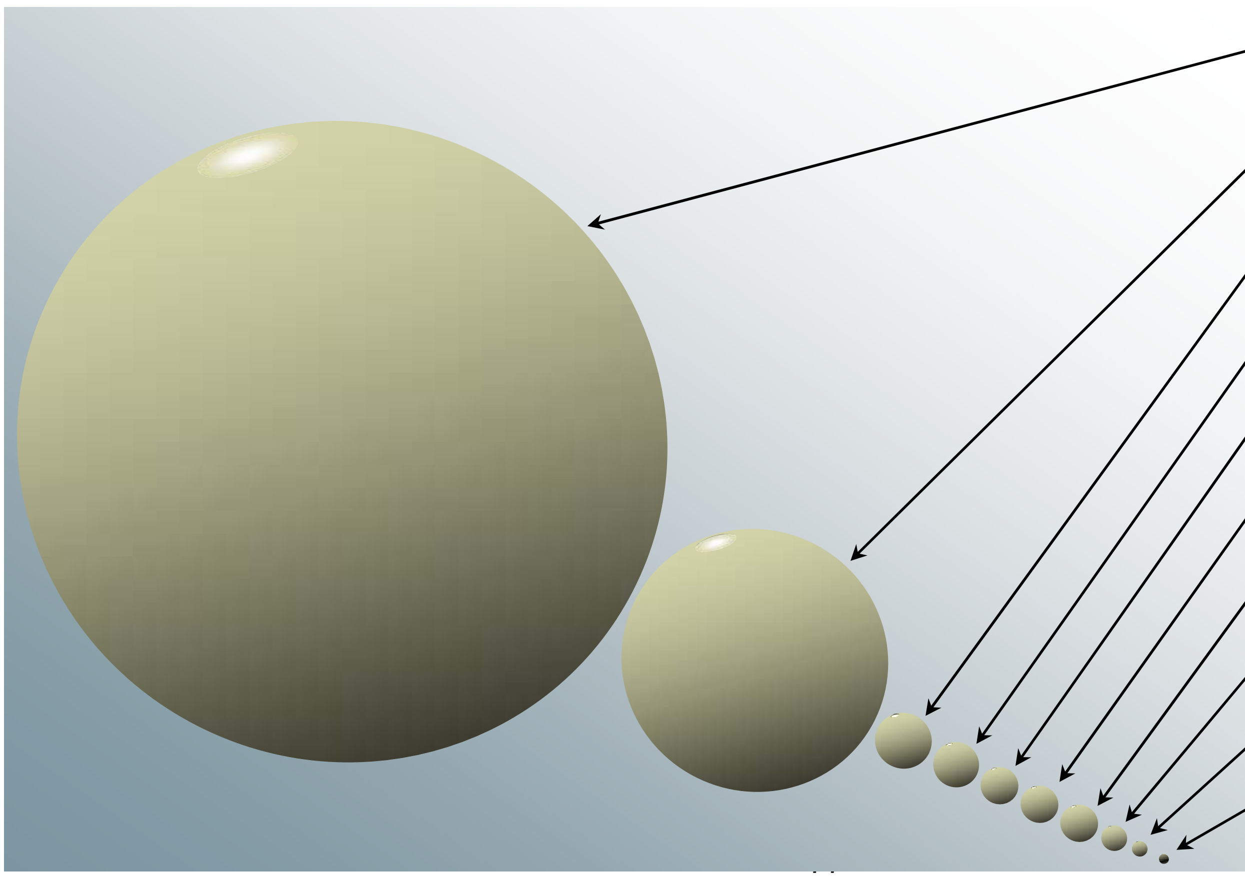
Typical Long-Range Error Sources

Ballistic Case = Ballistic projectile dispensing submunitions at 70 degree angle

$(MET^2 + Prop^2 + NORTH^2 + Site^2 + drift^2 + TLE^2 + Vert^2 + NAV^2 + Guide^2 + Control^2)^{1/2} =$ 317 meters

Guided Case = Ballistic projectile dispensing submunitions at 70 degree angle

$(MET^2 + Prop^2 + NORTH^2 + Site^2 + drift^2 + TLE^2 + Vert^2 + NAV^2 + Guide^2 + Control^2)^{1/2} =$ 22 meters



MET Error
100–1000 meters, typically 300

Propellant Error
50–300 meters, typically 100

Site NORTH Error
5–50 meters, typically 20

Submunition Drift Error
5–50 meters, typically 15

Target Location Error
5–100 meters, typically 30

Gun Site Error
5–50 meters, typically 10

Navigation Error
5–100 meters, typically 10

Projection Vertical Error
3–20 meters, typically 5

Guidance Miss Error
1–10 meters, typically 3

Control System Error
0.1–3 meters, typically 1

imited Distribution

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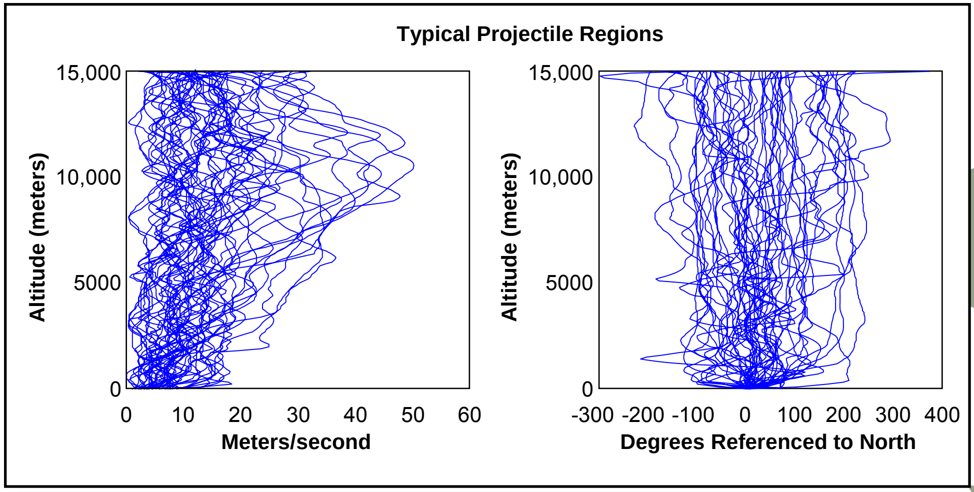
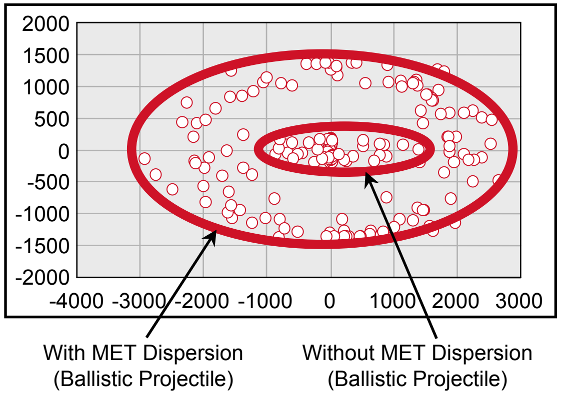
Winds Aloft

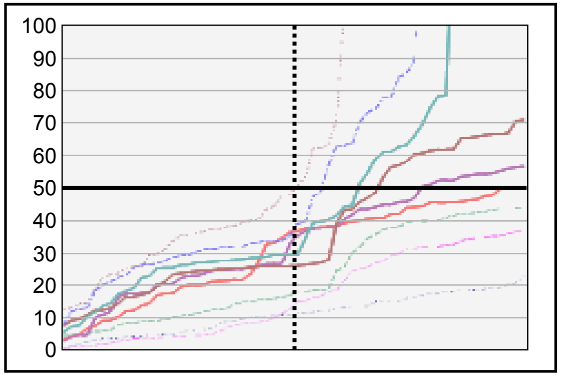
- Winds aloft a major determinant of system correction maneuver needed

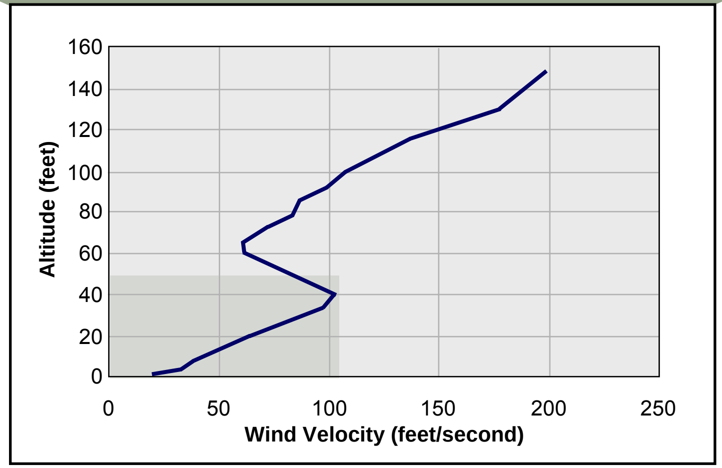
Examples of Winds Aloft Profiles (U.S. Air Force)



Winds aloft profiles will create large dispersions if systems are not robust







Rule:
Maneuverability must be greater than two times MPI to be MET tolerant

MPI — Mean Point of Impact

First Shot CEP

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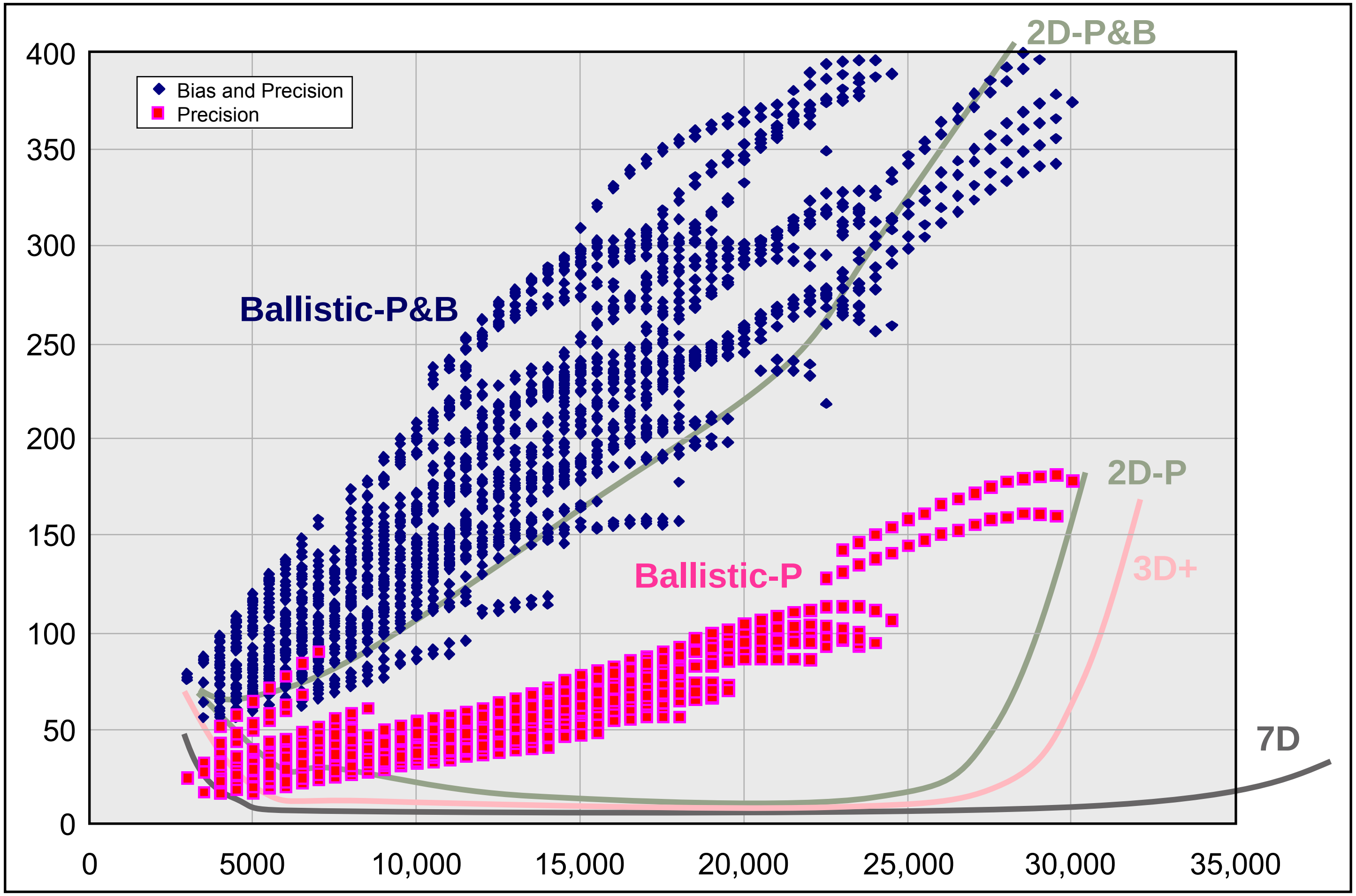
Missile Systems

- First shot CEP drives collateral damage potential

MET dominates errors determining bias for ballistic

Depending on system maneuverability, MET errors may have minor or major collateral damage influence



CEP — Circle of Equal Probability

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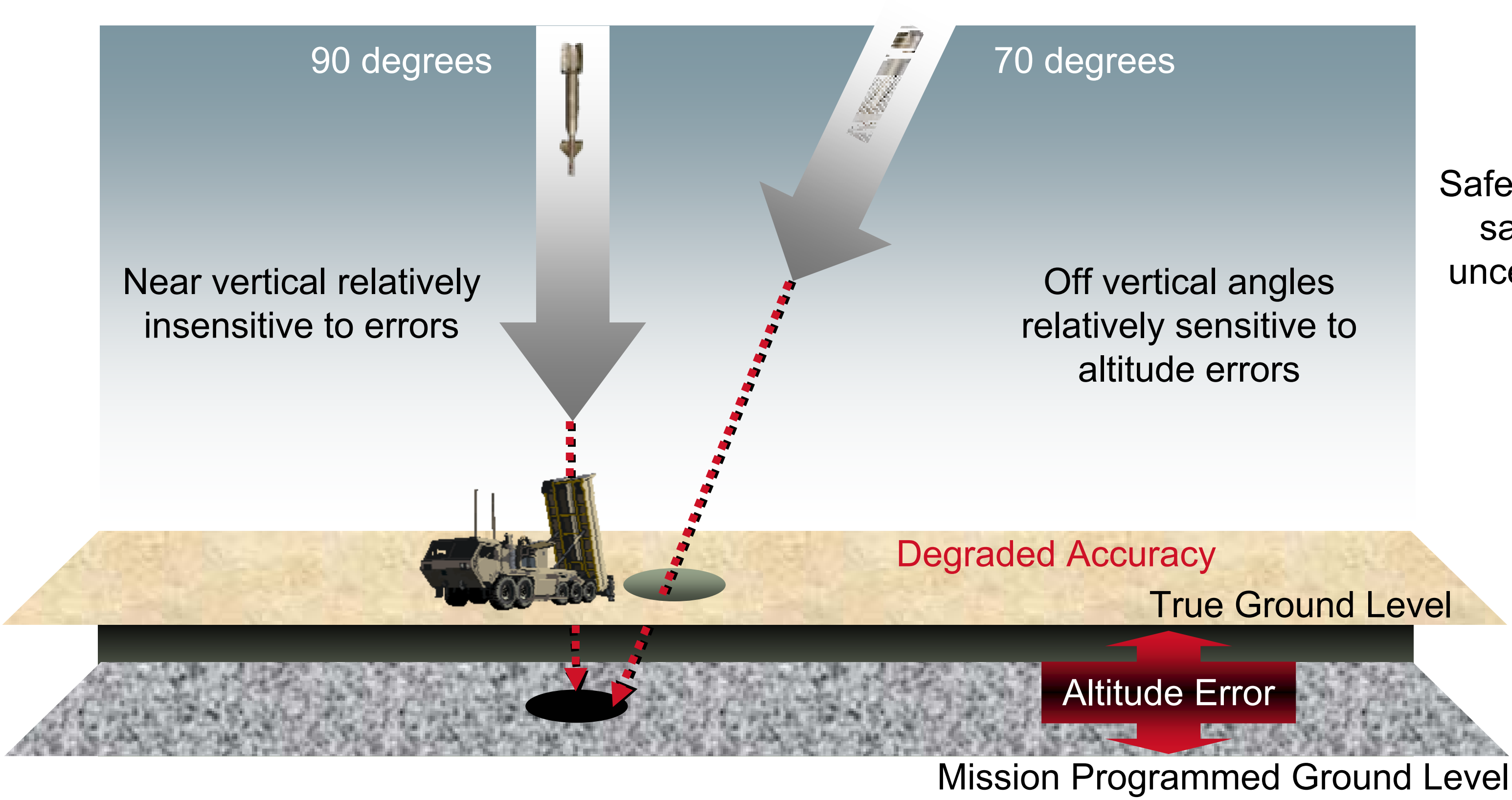
Vertical Errors

- Vertical errors causing horizontal miss

Horizontal Error Potential (70 degrees)

Source	Vertical (1s)	Horizontal (1s)
GPS	15.3 meters	5.1 meters
FO	10.0 meters	3.4 meters
DTED	18.8 meters	6.4 meters



Safe to shoot, safe with uncertainties

FO — Fixed Object
DTED — Digital Terrain Elevation Data

Verticality of MOUT

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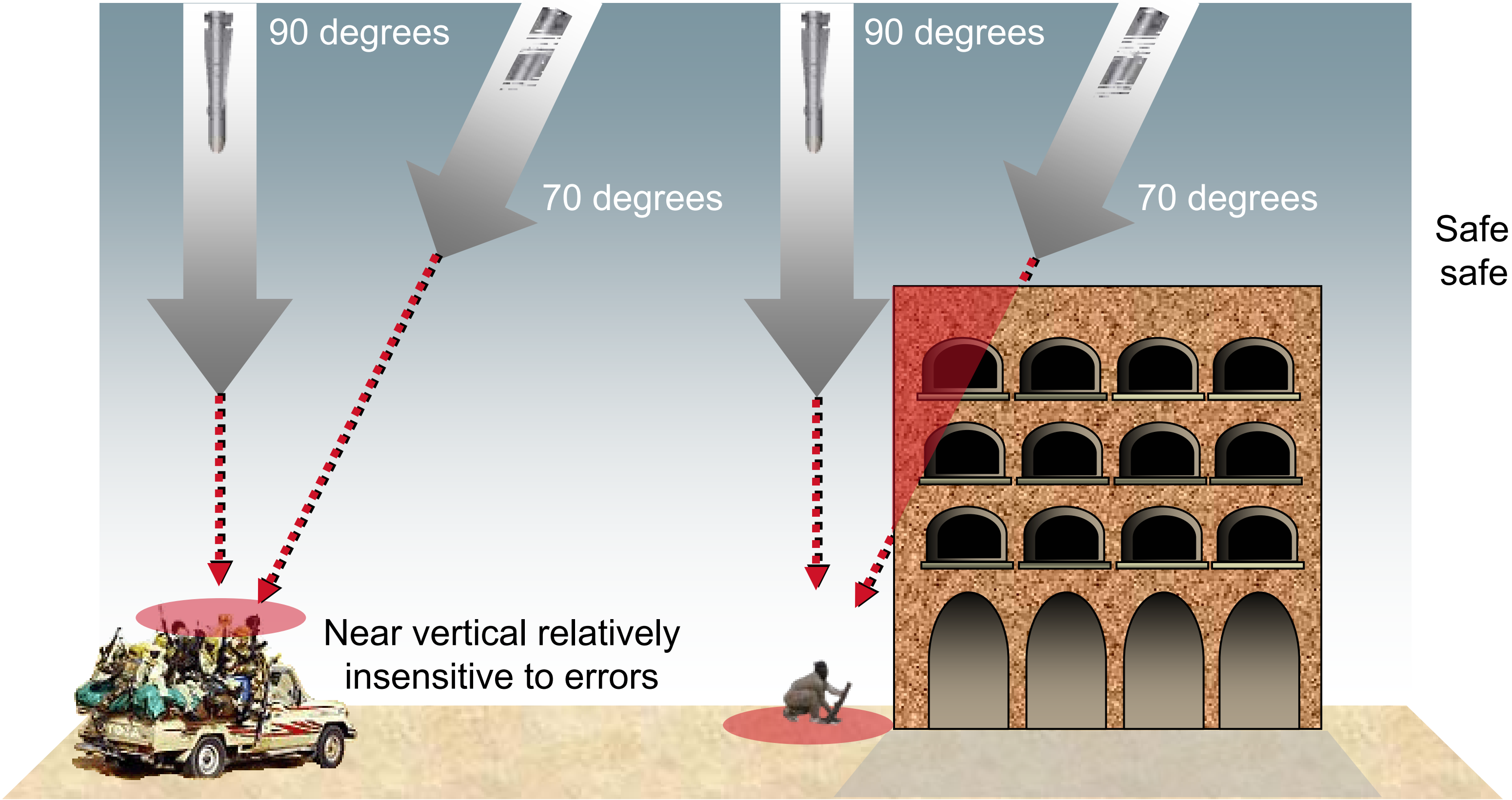
Missile Systems

- Verticality — MOUT — Risk of building impact

Vertical Error Potential (70 degrees)

Source	Vertical (1s)
GPS	15.3 meters
FO	10.0 meters
DTED	18.8 meters



Off vertical angles also sensitive to altitude errors

Safe to shoot, safe if MOUT

No Vertical Errors

True Ground Level

MOUT — Military Operations on Urban Terrain

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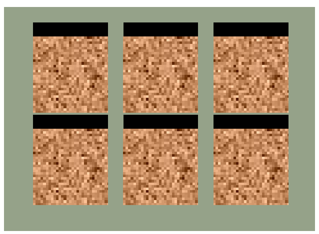
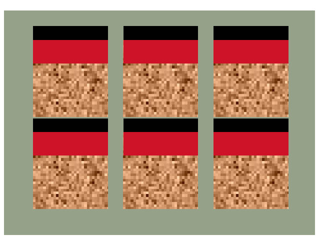
MOUT/Complex Terrain — Fire Line

- Management of target shadowing versus threats of collateral damage caused by structure strikes

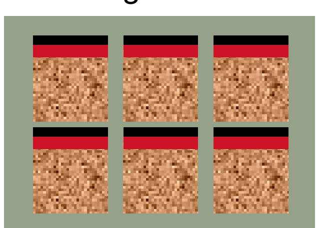
Best Case
(Gun is parallel with roads)



Risk of Building Strike 60 degrees



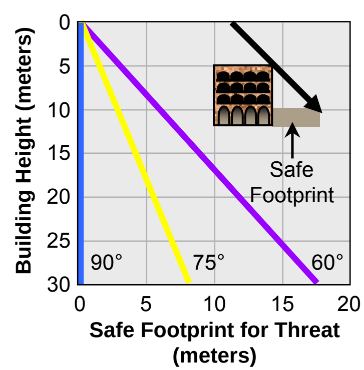
Risk of Building Strike 90 degrees



Open area that can be engaged by indirect fire

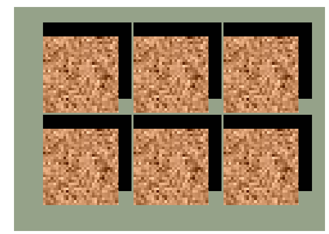
Open area that cannot be engaged because of building

Collateral risk area



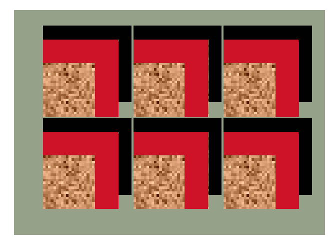
Note — with 7D, terminal azimuth angles can be aligned to obstructions

Worst Case
(Gun is 45 degrees to buildings)

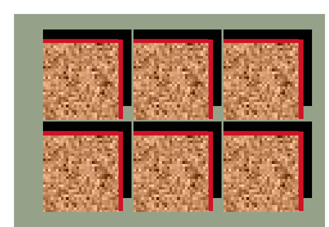


Safe to shoot, safe if MOUT

Risk of Building Strike 60 degrees



Risk of Building Strike 90 degrees



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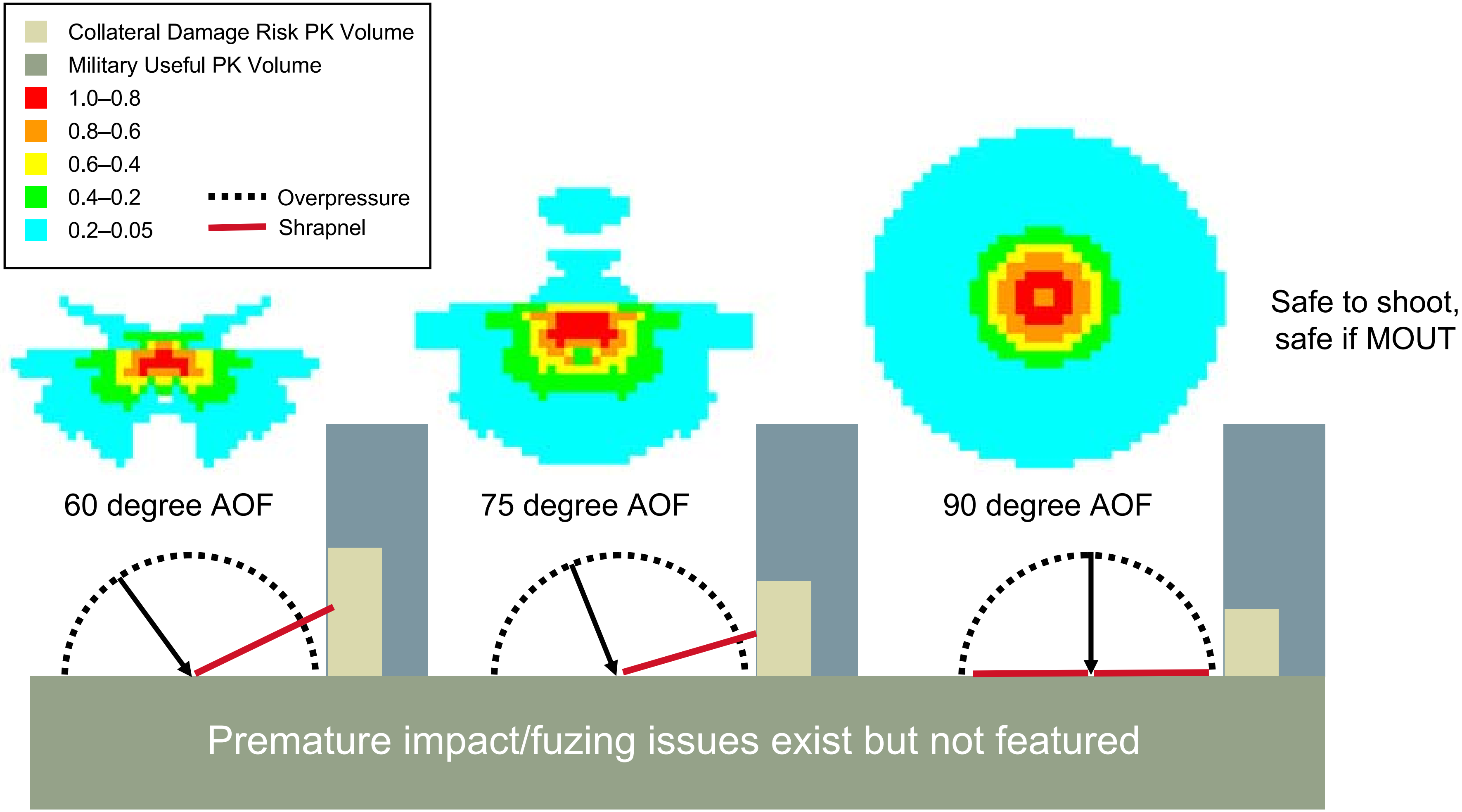
Urban Terrains — Verticality/Lethality

- Management of impact angle of where fragments might go



AOF — Azimuth of Fire
PK — Probability of Kill

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Payload Lethality

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Missile Systems

Joules required to damage target

Target	Light Damage	Moderate Damage	Heavy Damage
Personnel	0.1	1	4
Aircraft	4	10	20
Armor	10	500	1000

Initial Fragment Velocity

The theoretical result for fragment velocity using the Gurney constant (2ΔE) for TNT is 2328 m/s:

$$v = \sqrt{2\Delta E}\sqrt{\frac{C/M}{1+K(C/M)}}$$

where:

C/M is the charge-to-metal ratio

K depends on the configuration:
Flat plate: K = 1/3
Cylinder: K = 1/2
Sphere: K = 3/5

Probability of Kill

$$N_{hits} = A(N_o/4\pi R^2)$$

where:

N_{hits} is the expected number of fragments hitting

N_o is the initial number of fragments from the warhead

A is the frontal area of the target presented to the warhead

R is the range of the target to the warhead

For multiple hits the overall P_k is found from

$P_k = 1 - (1-P_K|_{hit})^{N_{hits}}$, if $N_{hits} > 1$, or MISSING TEXT?

Fragment Velocity at Range

$$V(s) = V_o * e^{-\rho C_d A s/2M}$$

ρ = The density of air. Normally 1.2 Kg/m3

V_o = The fragment velocity

C_d = The coefficient of drag[1]

A = The cross-sectional area of the fragment

M = Mass of fragment

s = Distance traveled

1 Depends on shape of the fragment and velocity

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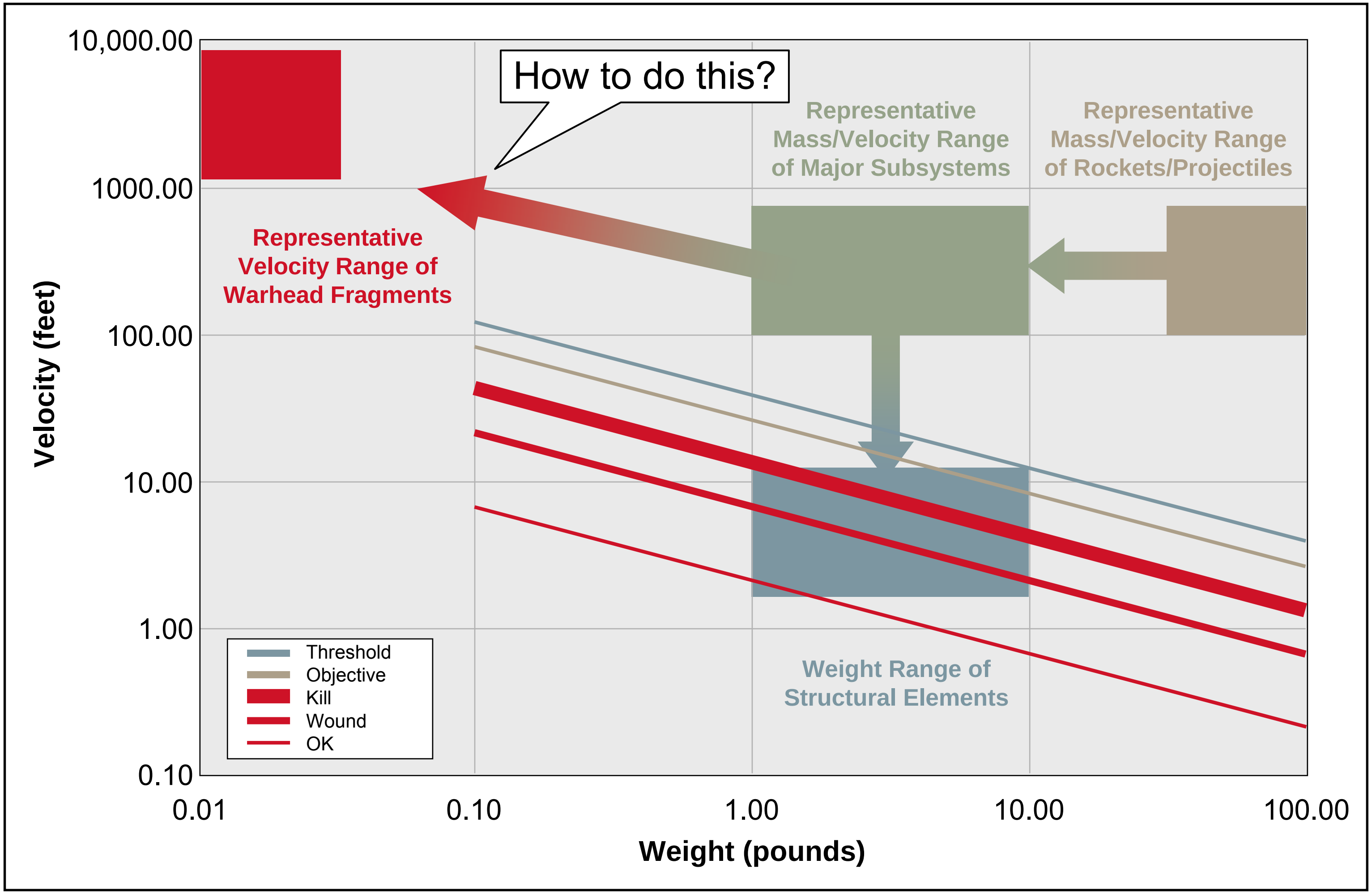
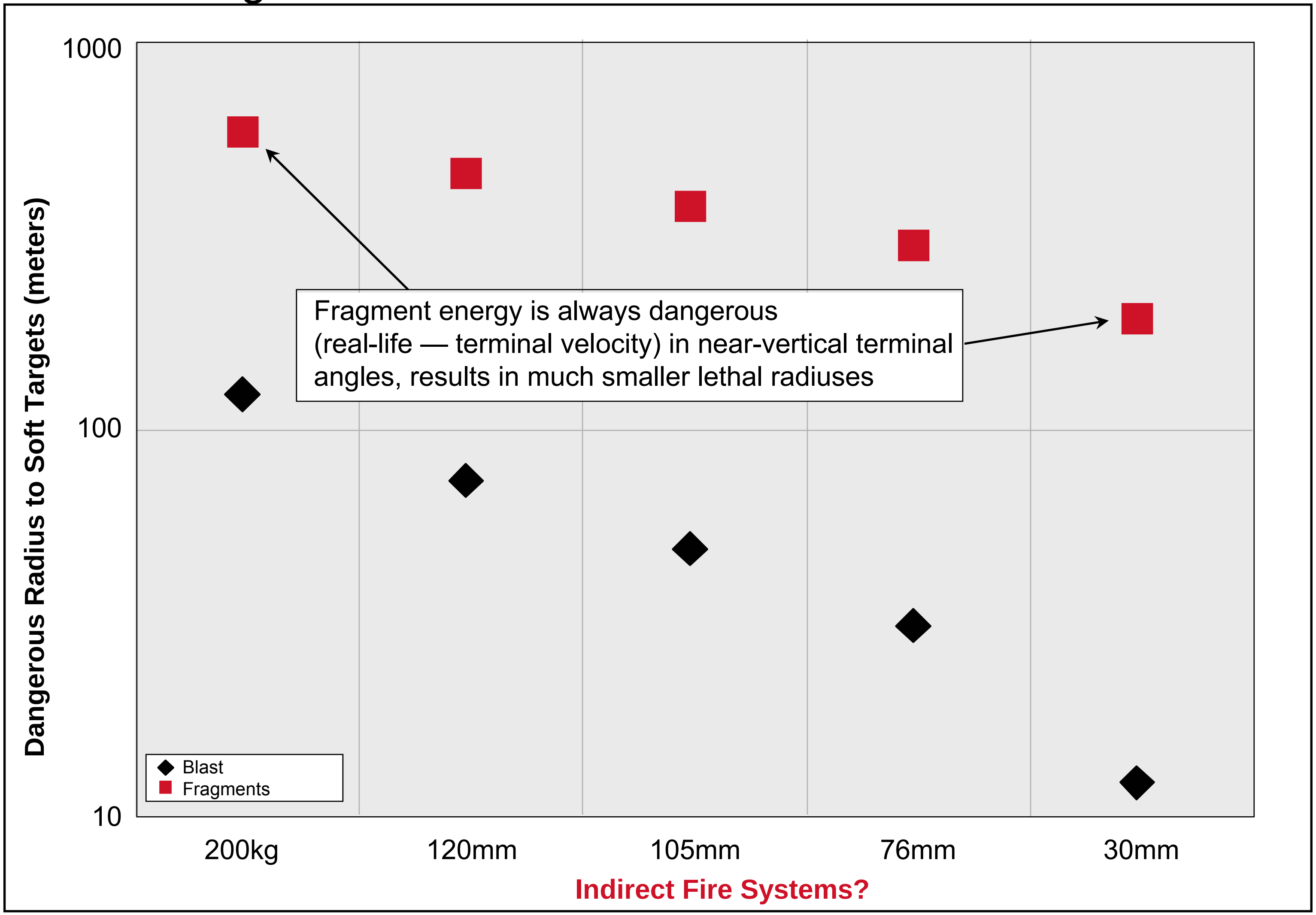
Warheads Too Big

- Collateral damage can be managed only with precision and attitude



Warhead Size Lethality

- Collateral damage radius



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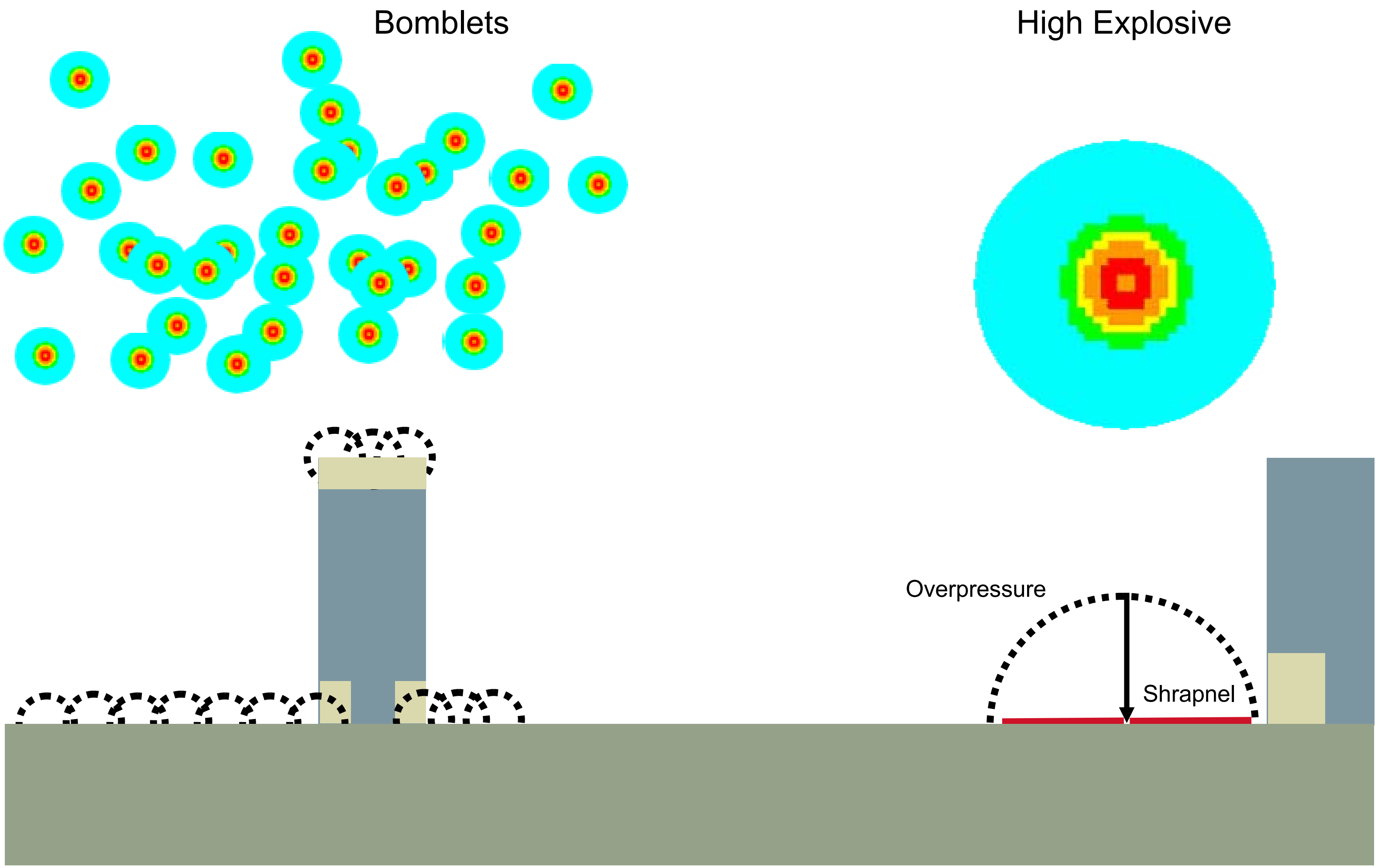
Projectile Type

- Management of collateral damage area



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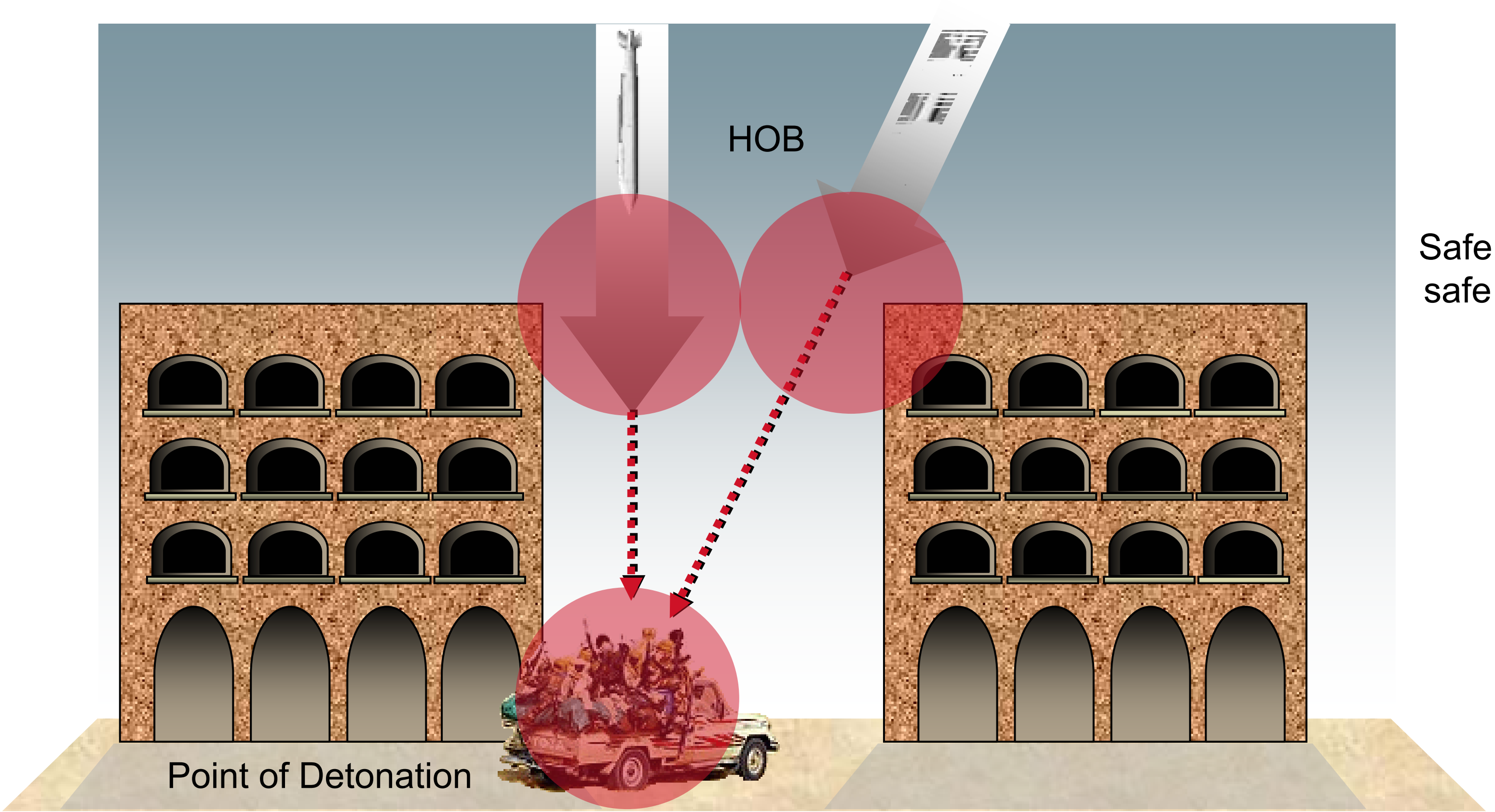
Fusing

- Clutter induced pre-detonation



Safe to shoot,
safe if MOUT

Probability of Collateral Damage

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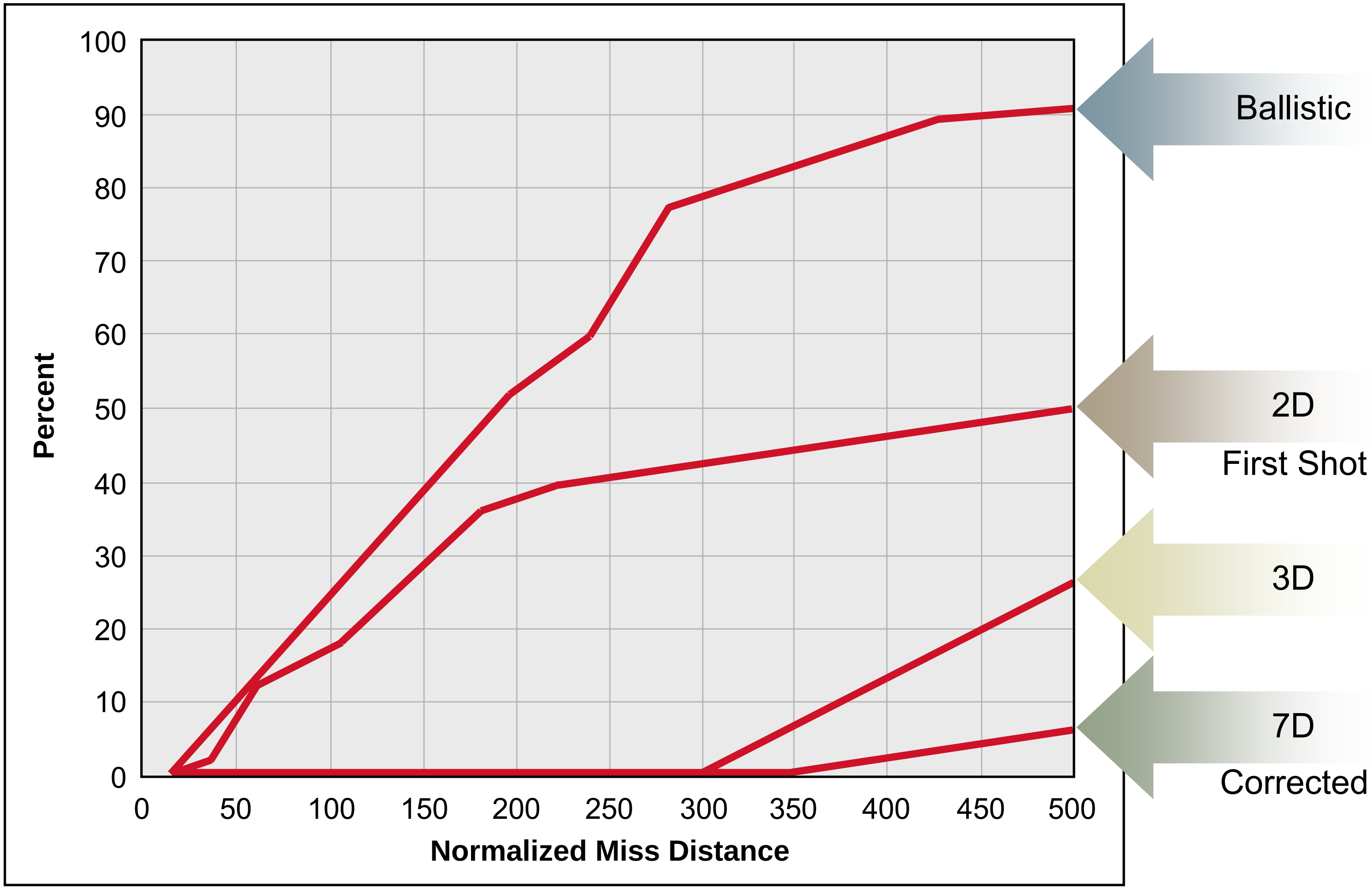
Missile Systems

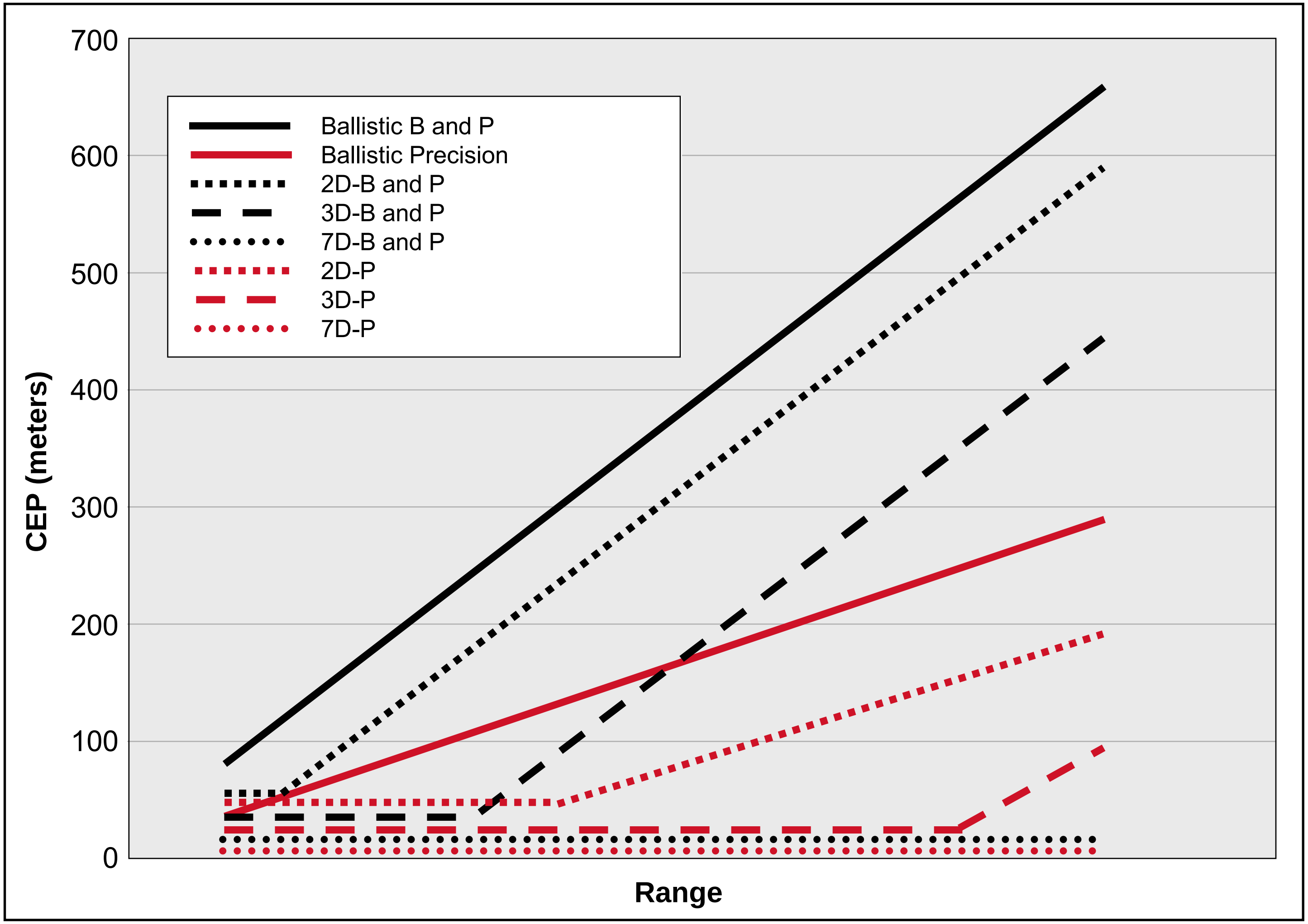
- Probability of causing collateral damage inducing miss



Safe to shoot, safe if MET/Gun bad

Projectile Maneuverability

- How much aiming error to remove or provide safety margin



Safe to shoot, safe if MET/Gun bad

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Summary

Raytheon Missile Systems

- Precision is the key
  - Highest leverage – hit what you aimed out
  - Permits considering smaller warhead energy
    - Not yet a major factor — fractional damage per shot still rules
    - At least opens the door to softer warheads
  - Elimination of large potential kinematic hazards
- Matching of MET/GUN uncertainties to weapon maneuver potential
- Control of Delivery is very important
  - Verticality to avoid horizontal errors
  - Off axis to minimize shadowing and obstacles
- Fuzing must consider real world
  - Multiple options to avoid pre-detonations
  - Terminal trajectory to minimize pre-detonation
- Warheads presently design to maximize lethality
  - Size of fragments
  - Type (unitary, penetrator or submunitions)

Questions

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Missile Systems

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IM Explosive for SMAW HEAA Warhead

N. C. Johnson, C. W. Gonzalez, K. W. Reed, L. A. Kowalczyk, W. L. Myers, V. L. Beam, and V. A. Fields

Indian Head Division, Naval Surface Warfare Center
Indian Head, MD

April 8, 2009
NDIA Gun and Missile Systems Conference

Presentation Outline

- Objectives
- Approach
- System Description
- Explosive Selection
- Qualification and Performance Tests
- Summary
- Acknowledgements

Objectives

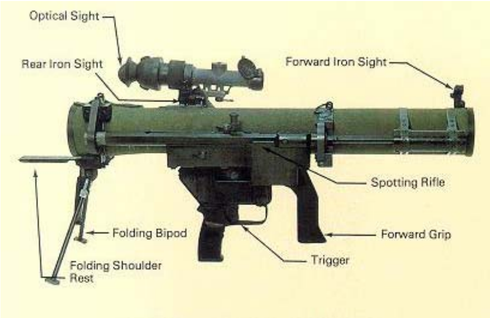
- Replace SMAW HEAA warhead fill (Octol) with explosive of comparable performance and improved IM characteristics
  - Sponsor directive: only system change will be explosive fill
- Meet current HEAA penetration requirements
- Qualify SMAW HEAA with IM warhead fill (SMAW HEAA-IM Warhead)

Approach

- **Phase I: Explosive Selection**
  - Explosive Selection Committee
  - IM and Performance Testing in SMAW HEAA Warhead
  - Downselection to Final Explosive Fill
- **Phase II: Qualification and Performance Testing SMAW HEAA-IM Warhead**

SMAW HEAA System Description

- Shoulder-launched Multi-purpose Assault Weapon High Explosive Anti-Armor
- DODIC HX06
- Effective against medium armor
- SMAW HEAA consists of:
  - MK 153 MOD 0 Launcher
  - SMAW HEAA Encased Assault Rocket (EAR)
- SMAW HEAA Rocket consists of:
  - Rocket motor
  - Impact fuze
  - Shaped charge, high explosive warhead



REUSABLE SMAW LAUNCHER

Selection of IM Explosive Candidates

Explosives Assessment

- Explosive Output
- IM Survivability
- Safety & Reliability
- Producibility / Life Cycle Costs

Explosive Candidates

- PBXN-9
  - Used in Navy & Army shaped charge ordnance
  - Good IM in FCO/SCO/BI
  - Bad IM in FI
- PBXN-11
  - Better performance than PBXN-9
  - Good IM in FCO/SCO
  - Bad IM in BI/FI
- PBXW-114
  - Equivalent performance to PBXN-110
  - Good IM in FCO/SCO/BI
  - Potential for significant improvement in FI

Explosive Properties

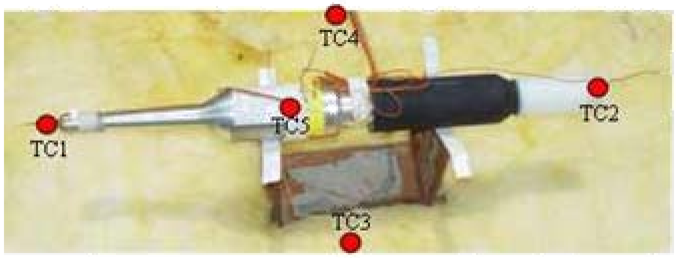
Explosive	Composition	Manufacture Method	Density, g/cc	FCO/SCO/BI
PBXN-9	HMX/binder	pressed	1.73	V/V/V
PBXN-11	HMX/binder	pressed	1.80	V/V/IV
PBXW-114	HMX/Al/binder	cast	1.71	V/V/V
Octol	HMX/TNT	melt (sedimentation) cast	1.82	I/I/V

Phase I. IM and Performance Tests

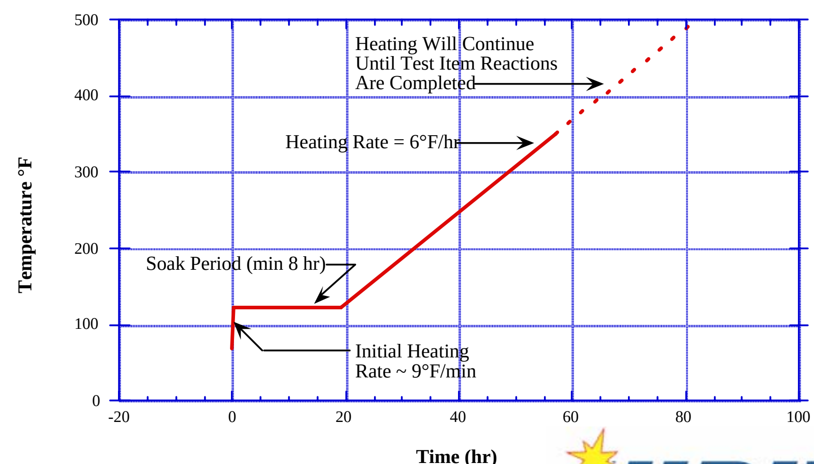
Phase I Testing

- Slow Cook-Off
  - 2 warheads of each explosive fill plus Octol baseline
  - Tests performed at Dahlgren Division, NSWC
- Fragmentation Impact
  - 2 warheads of each explosive fill plus Octol baseline
  - Tests performed at Dahlgren Division, NSWC
- Penetration
  - 3 warheads of each explosive fill (2 for PBXN-11) plus Octol baseline
  - Tests performed at Dahlgren Division, NSWC
- Flash X-ray
  - 2 warheads of PBXN-9 and PBXW-114 fills plus Octol baseline
  - No PBXN-11 loaded warheads available
  - Tests performed at ARL, Aberdeen, MD

Slow Cook-Off Test



- MIL-STD-2105C (STANAG 4382)
- 2 tests per explosive candidate and Octol baseline
- Live warhead, other components were inert mass simulates
- Six thermocouples recorded temperatures
- Tests were continuously monitored by two video cameras
- Photographs of test set-up and post test results taken



Slow Cook–Off Results

Explosive	Reaction
PBXN-9	Type IV (Deflagration)
PBXN-11	Type V (Burn)
PBXW-114	Type IV (Deflagration)
Octol	Type I (Detonation)

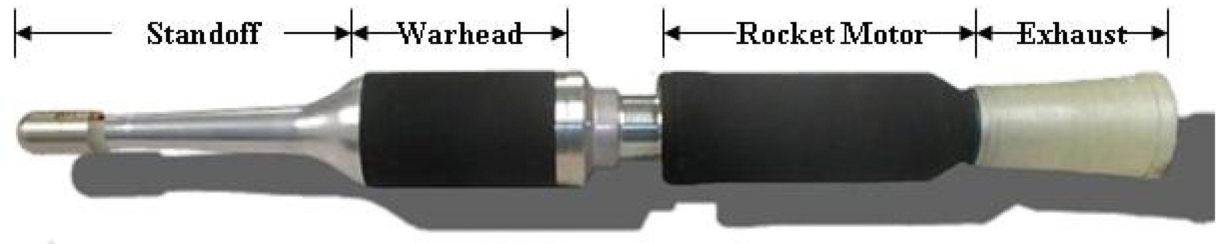
PBXN-11 post test

Octol post test

Slow Cook-Off

Liner Ejected from Warhead in all SCO tests of Explosive Candidates

Fragment Impact Test



- MIL-STD-2105C (STANAG 4496)
- 2 tests per explosive candidate and Octol baseline
  - Fragment velocity ~8000 ft/sec first test; ~6000 ft/sec second test
- Live warhead, other components were inert mass simulates
- Pressure gauges @ 15’, 22’ and 34’
- 3 Foil velocity screens measured fragment velocity
- Test recorded using digital Phantom cameras

Fragment Impact Results

Explosive	Reaction
PBXN-9	Type I (Detonation)
PBXN-11	Type I (Detonation)
PBXW-114	Type I (Detonation) & Type IV (Deflagration)
Octol	Type I (Detonation)

Warhead Penetration Tests

- 3 Tests per explosive candidate and Octol baseline
  - Except only 2 PBXN-11 warheads available
- Test continuously monitored by a video cameras
- Photographs of test set-up and post test results taken

Explosive	Average Penetration
PBXN-9	passed
PBXN-11	passed
PBXW-114	failed
Octol	baseline

PBXN-11 Loading

- Problems encountered loading PBXN-11 charges
- PBXN-11 tended to adhere to case wall when pressed under conditions used for PBXN-9 charges and caused case deformation
- PBXN-11 charges for tests were pressed as free-standing billets, slipped into warhead case, and then pressed lightly
- Loading process improvement required if PBXN-11 selected

Summary of Phase I Results

Explosive	Density	Current Processibility	Penetration	IM Reactions		
				SCO	Frag Impact (T1 8000 ft/sec, T2 6000 ft/sec)	
PBXN-9	1.744 1.744 1.750	Yes	passed	IV (2) Deflagration	I (2) Detonation	
PBXN-11	1.769 * 1.803	No	passed	V (2) Burn	I (2) Detonation	
PBXW-114	~1.71	Yes	failed	IV (2) Deflagration	I (1) Detonation	IV (1) Deflagration
Octol	1.80-1.85	N/A	baseline	I (2) Detonation	I (2) Detonation	
	* 98% TMD is 1.793 gm/cc. 1.769 is 96.7% TMD					

IM Explosive Selection

- PBXN-9 Selected
- Based on
  - Performed well in penetration tests
  - IM characteristics
  - Fielded as main charge in other shaped charge warheads
  - Drop in solution
- Place barrier tape between PBXN-5 booster and PBXN-9 explosive
- Informally refer to SMAW HEAA system with PBXN-9 warhead fill as "SMAW HEAA-IM Warhead"

Phase II. Qualification and Performance Tests for SMAW HEAA-IM Warhead

Qualification and Performance Tests

- Objectives
  - Ensure that SMAW HEAA-IM Warhead meets IM and Hazard Classification (HC) requirements
  - Obtain Final (Type) Qualification of the SMAW HEAA-IM Warhead
  - Verify that replacement of warhead fill has not caused degradation of system performance

Phase II Tests

- Test Items
  - Built by Nammo Talley, Inc.
  - Warheads loaded by IHDIV, NSWC
  - Liners are Government Furnished Material (GFM)
  - Mk 259 Fuzes are GFM

- Testing will be conducted by National Technical Systems (NTS), Camden, Arkansas during March – June 2009

Qualification Tests

Tests harmonized for IM and HC Purposes, but include only a limited subset of HC and FTQ tests, since this effort is only changing the warhead explosive fill and not safety features of the system

- Basic Safety Tests w/ Thermal Stability
- Sympathetic Detonation (Stack Test)
- Fast Cook-Off
- Slow Cook-Off
- Bullet Impact
- Fragment Impact

Phase II Test Matrix

	Configuration	Live WH w/ Booster	Rocket Motor		Fuze		Spotting Round	
			Live	Inert	Live	Inert	Live	None
28-day T&H, Thermal Stability, Vibration, 4-day T&H, 40 ft. drop	Shipping Configuration	1		1		1	1	
		1		1		1	1	
		1		1		1	1	
28-day T&H, Thermal Stability, Vibration, 4-day T&H, Flight Performance Testing		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
Flight Performance Testing (Baseline)	EAR	1	1		1		1	
	EAR	1	1		1		1	
Sympathetic Detonation - Confined Stack Test	Shipping Configuration	1		1		1	1	
		1		1	1		1	
		1		1	1		1	
		1		1	1		1	
		1		1	1		1	
		1		1	1		1	
		1	1		1		1	
Sympathetic Detonation - Unconfined Stack Test	Shipping Configuration	1		1		1	1	
		1		1	1		1	
		1		1	1		1	
		1		1	1		1	
		1		1	1		1	
		1	1		1		1	
		1	1		1		1	
Fast Cook Off	Shipping Configuration	1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
		1	1		1		1	
Fast Cook Off	EAR	1		1		1	1	
Slow Cook-Off	EAR	1		1		1		1
	EAR	1		1		1		1
Bullet Impact	EAR	1		1		1		1
	EAR	1		1		1		1
Fragment Impact	EAR	1		1		1		1
	EAR	1		1		1		1

Phase II Test Matrix

(continued)

	Configuration	Live WH w/ Booster	Rocket Motor		Fuze		Spotting Round	
			Live	Inert	Live	Inert	Live	None
3 Month Aging, Penetration Testing	WH only	1						
	WH only	1						
	WH only	1						
6 Month Aging, Penetration Testing	WH only	1						
	WH only	1						
	WH only	1						
Vibration, Penetration Testing	WH only	1						
	WH only	1						
Baseline Penetration Testing	WH only	1						
	WH only	1						

Summary

- PBXN-9 selected as IM explosive for SMAW HEAA warhead
- Qualification test plan received concurrence from WSESRB, NOSSA, DDESB, and Navy, Army & Air Force Hazard Classification Offices
- Warheads have been loaded
- Test items have been built
- Qualification and performance testing is underway

Acknowledgments

- Sponsor: Marine Corps Systems Command Program Manager for Ammunition (PM Ammo)
  - Program Manager: Richard Dooley
  - Engineer: Richard Hardy
  - Technical Advisor: Tim Portner, Dahlgren Division, NSWC

- Test item build: Nammo Talley, Inc.
  - Project Manager: Will Betush
  - Project Engineer: Glade Hansen

- Contact information:

  - Nancy Johnson
  - Indian Head Division, Naval Surface Warfare Center
  - Phone: 301-744-2575
  - Email: nancy.c.johnson1@navy.mil

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GD-OTS Super 40mm High Explosive Air Burst – Trace Program

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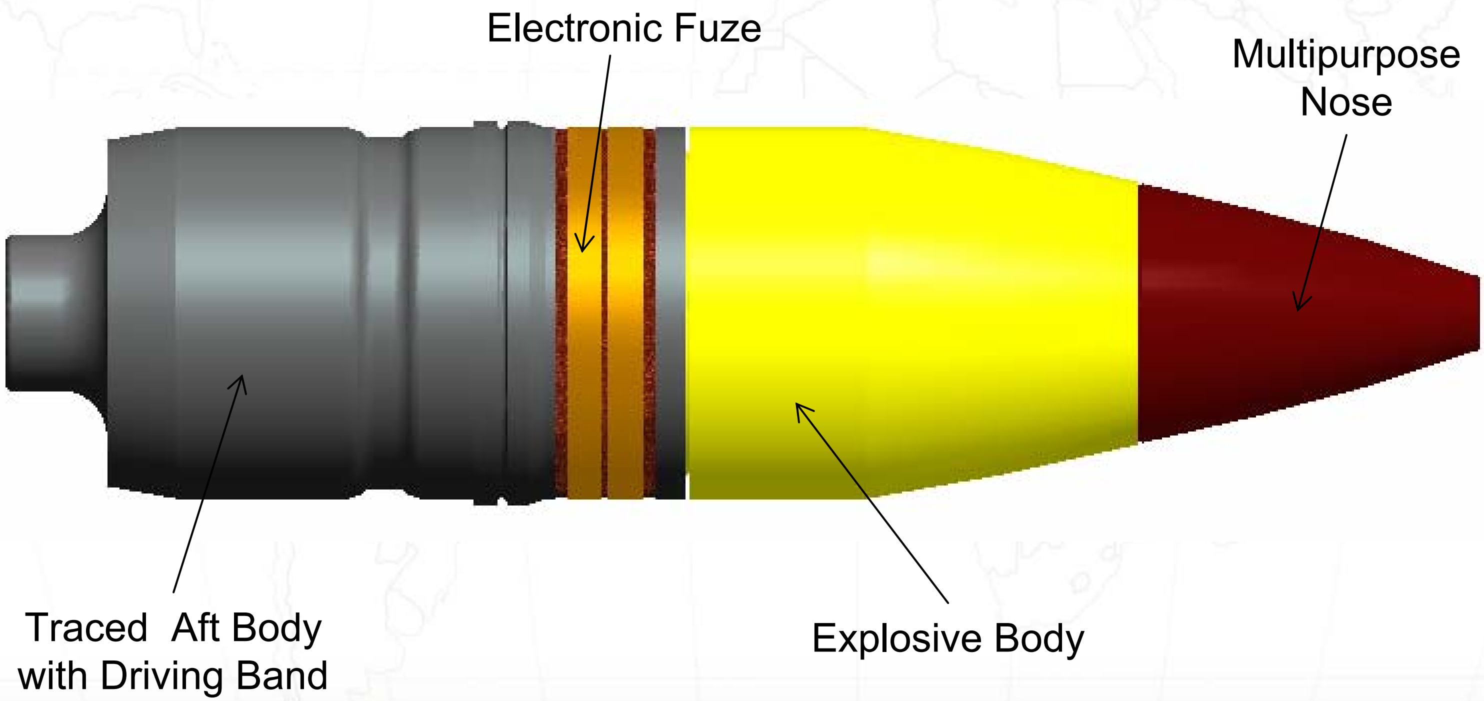
S40mm Air Burst Overview

For the last several years, GD-OTS has invested funds into the development of a S40mm High Explosive Air Burst – Trace (HEAB-T) Cartridge.

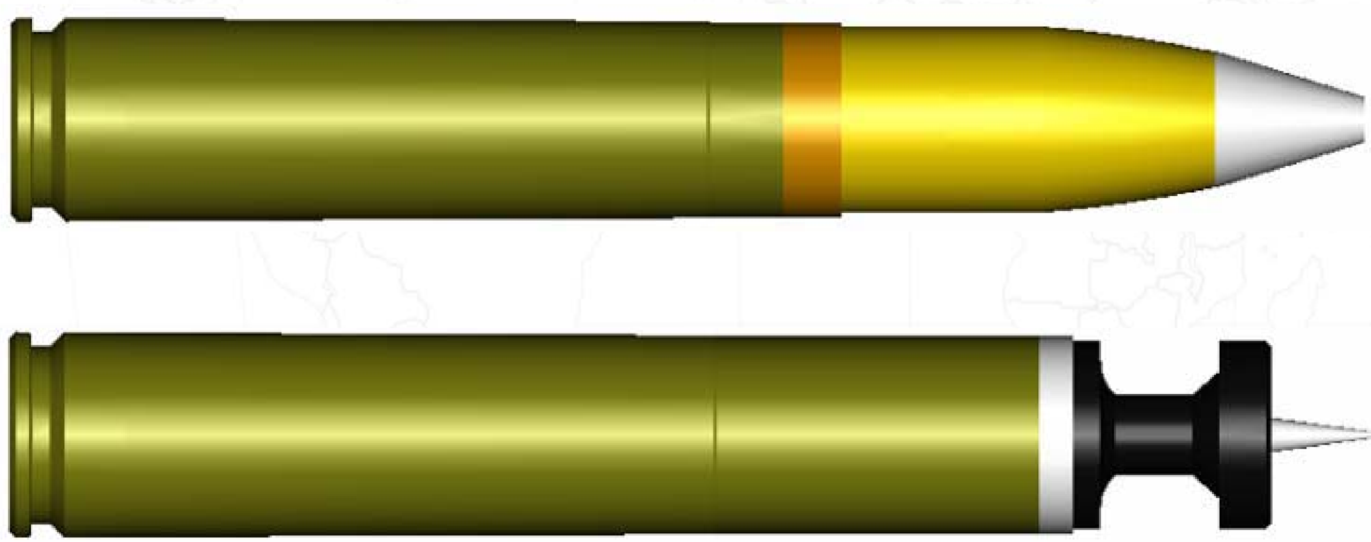


S40mm Air Burst Features

- Common case length with the APFSDS-T cartridge
- Incendiary filled, multipurpose nose
- Contact set, time-based, electronic fuze
- Lethal, fragmenting explosive body

S40mm – Common Case

- Original HEAB-T design utilized a 165mm long case, much shorter than the 218mm case for the APFSDS-T
- In addition to not being common with the APFSDS-T, the 165mm case allowed ~2" of free travel in the barrel causing excess barrel wear
- Parametric study was performed to determine the optimal common case length

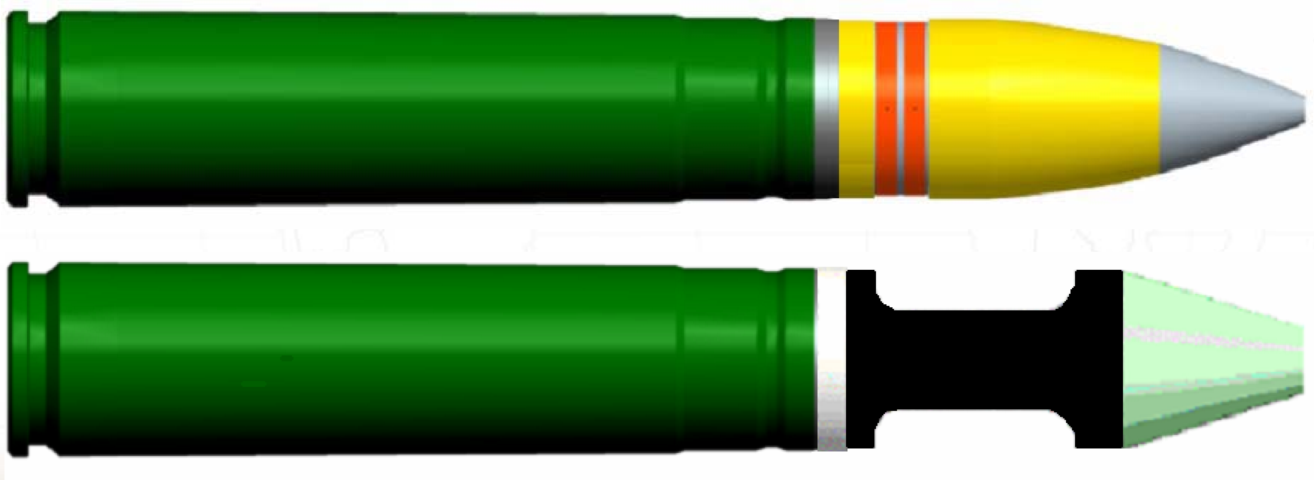


S40mm HEAB-T

S40mm APFSDS-T

S40mm – Common Case

- Outcome of parametric study was a 180mm case. This solution:
  - Locates forward edge of driving bands at forcing cone resulting in decreased barrel wear
  - Provides adequate area for communication and bearing surface in the HEAB-T
  - Allows for acceptable taper for case extraction



S40mm
HEAB-T

S40mm
APFSDS-T

S40mm Air Burst – Multipurpose Nose

- The HEAB contains a multipurpose nose to:
  - Increase capability of the ammunition and eliminate the need for HEI PD ammunition
  - Defeat light materiel targets
  - Provide PD function in the unlikely event that an air burst communication signal fails

S40mm Air Burst Fuze Description

- Programmable electronic time-based fuze
- Precision air burst function
- Contact communication system
- Fuze powered and set in weapon feed system
- Fuze reset each time target is lased
- Scalable across: 25mmx137 → 30mmx173 → 30mmx113 → S40mm → 35mmx228 → 50mmx228
- Integration into the weapon system is similar across Bushmaster platforms

S40mm Air Burst Fuze Description

- **Fuze Setting Flexibility**
  - Fuze can be set and reset multiple times before commitment by pulling the trigger. This enables the user to change targets as needed.
  - Manual override is an additional capability in the event a range finder cannot lock on a target. The solution is a progressive or regressive string of pearls that can cover the target.

S40mm Air Burst – Demonstration

S40mm Air Burst – Demonstration

Summary

- A lethal S40mm air burst munition exists today
- The munition has been successfully demonstrated out of the MK44 cannon in both single and burst mode (200 spm) at multiple ranges
- The munition has been demonstrated against mannequins standing, prone, and behind a sandbag barrier. Fragment patterns have been scored by the Eglin Vulcan System
- Fuze is scalable across calibers with similar integration across Bushmaster platforms

Apache AH-64

30x113mm Target Practice Spotter

Alternative Training Ammunition

for the M788 TP

Apache AH-64

30x113mm Target Practice Spotter

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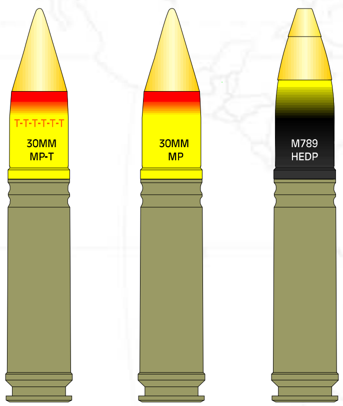
Overview

30mm x 113 Target Practice Spotter Cartridge

- Background
- Design Description
- Ballistic Performance
- Safety Compliance

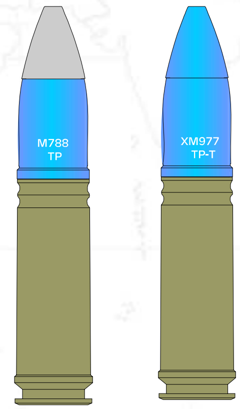
30mm x 113 Ammunition Family for M230 Gun

Tactical



PIE-T · PIE · HEDP

Training

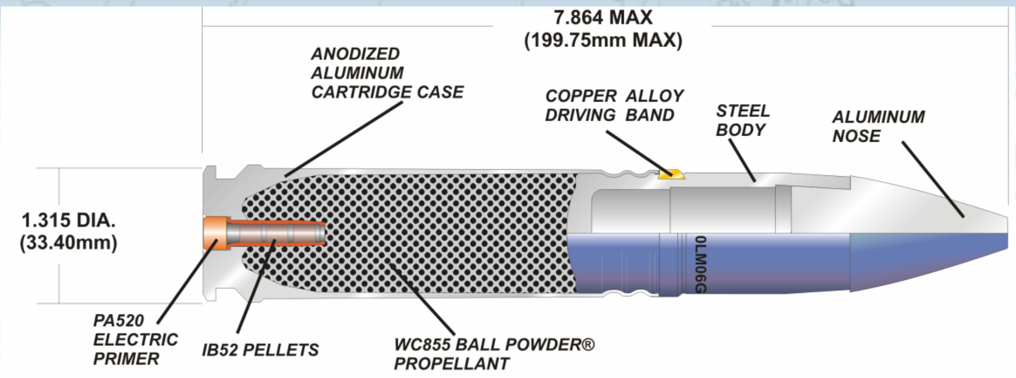


Spotter TP

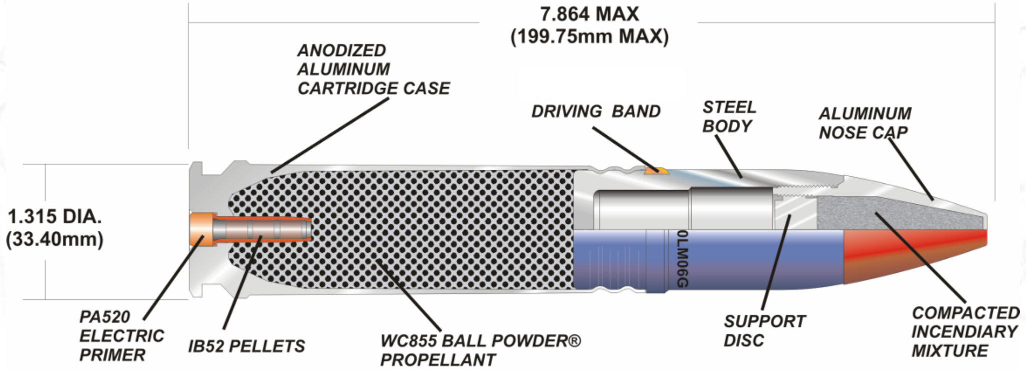
30mm x 113 Spotter Cartridge - Background

- In 2007 the US Army issued a Market Survey for an Apache training cartridge with a visible impact signature at ranges up to 3000m in day and night conditions while using an unaided eye, FLIR, night vision goggles, and day TV.
- The US Army invited contractors to participate in a technical demonstration at Ft Rucker in December 2007
- General Dynamics Ordnance and Tactical Systems delivered and demonstrated a 30mm x 113 Target Practice Spotter (TPS) cartridge for enhanced Apache M230 weapon training that is:
  - Compatible with the M230 weapon system
  - A ballistic match to the current M788 training ammunition
  - Visible under required conditions while impacting a steel target

30mm x 113 Target Practice Spotter Cartridge



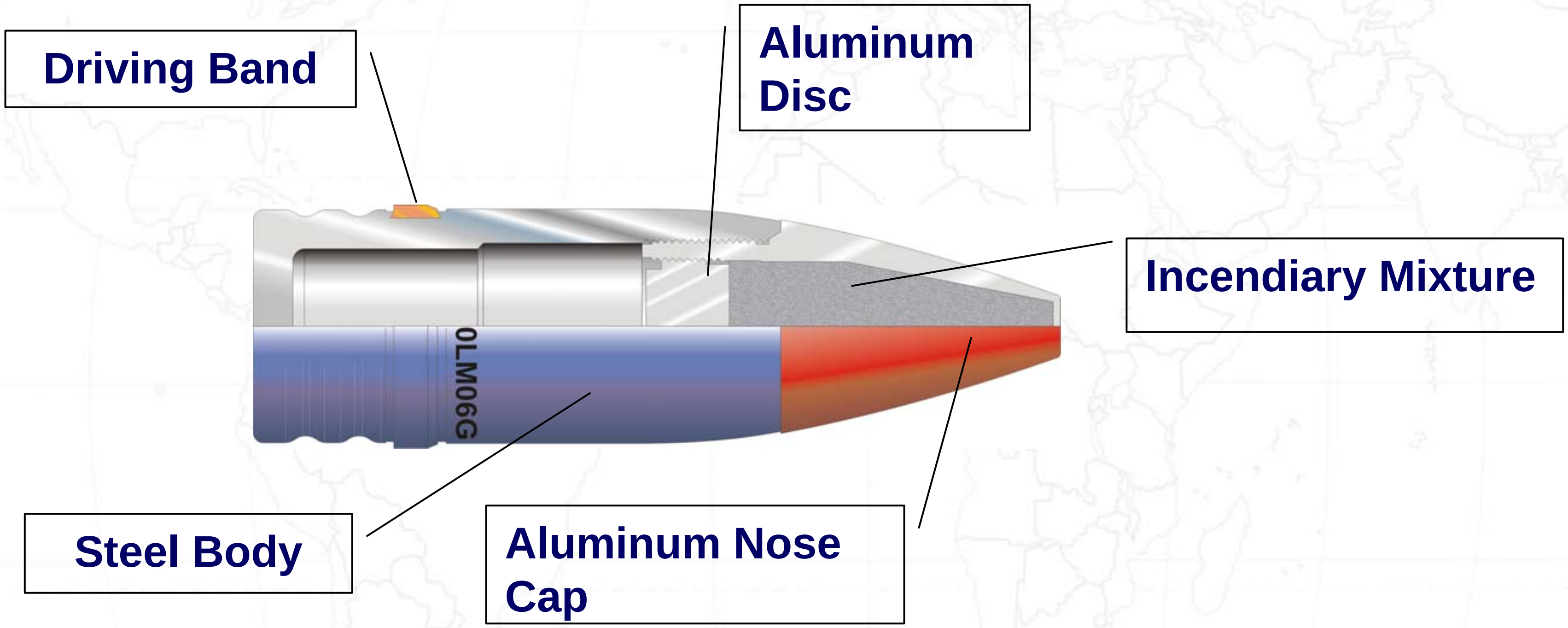
30mm x 113 TARGET PRATICE, M788



30mm x 113 TARGET PRATICE SPOTTER CARTRIDGE

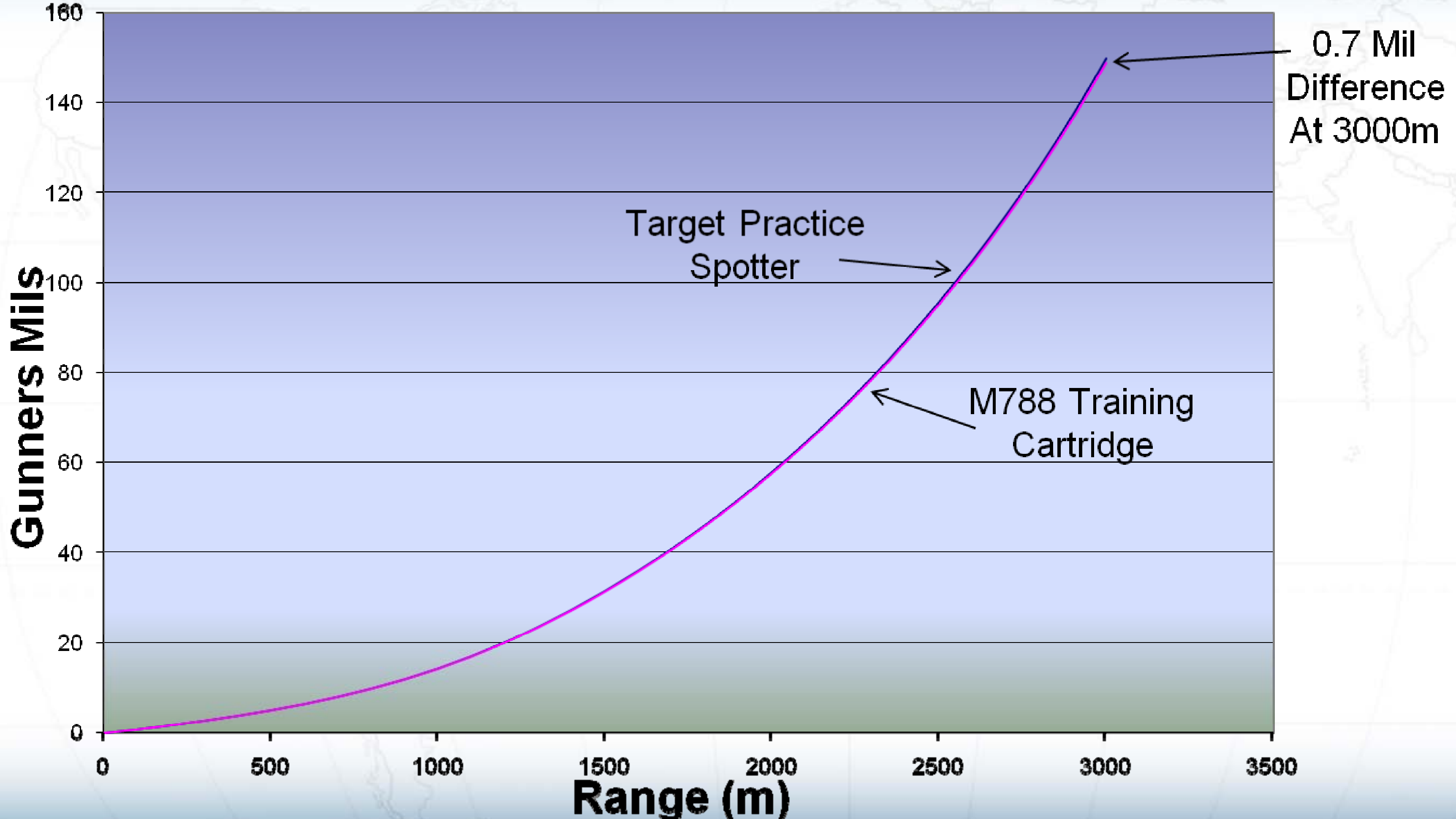
The 30mm Spotter Cartridge is Fully Compliant with the 30mm Gun System including Interior and Exterior Ballistic Performance

30mm x 113 Target Practice Spotter Projectile



GD-OTS Has Demonstrated Launch Survival and Reliable Function at Terminal Impact.

30mm x 113 Spotter Cartridge – Ballistic Match to M788 Training Cartridge



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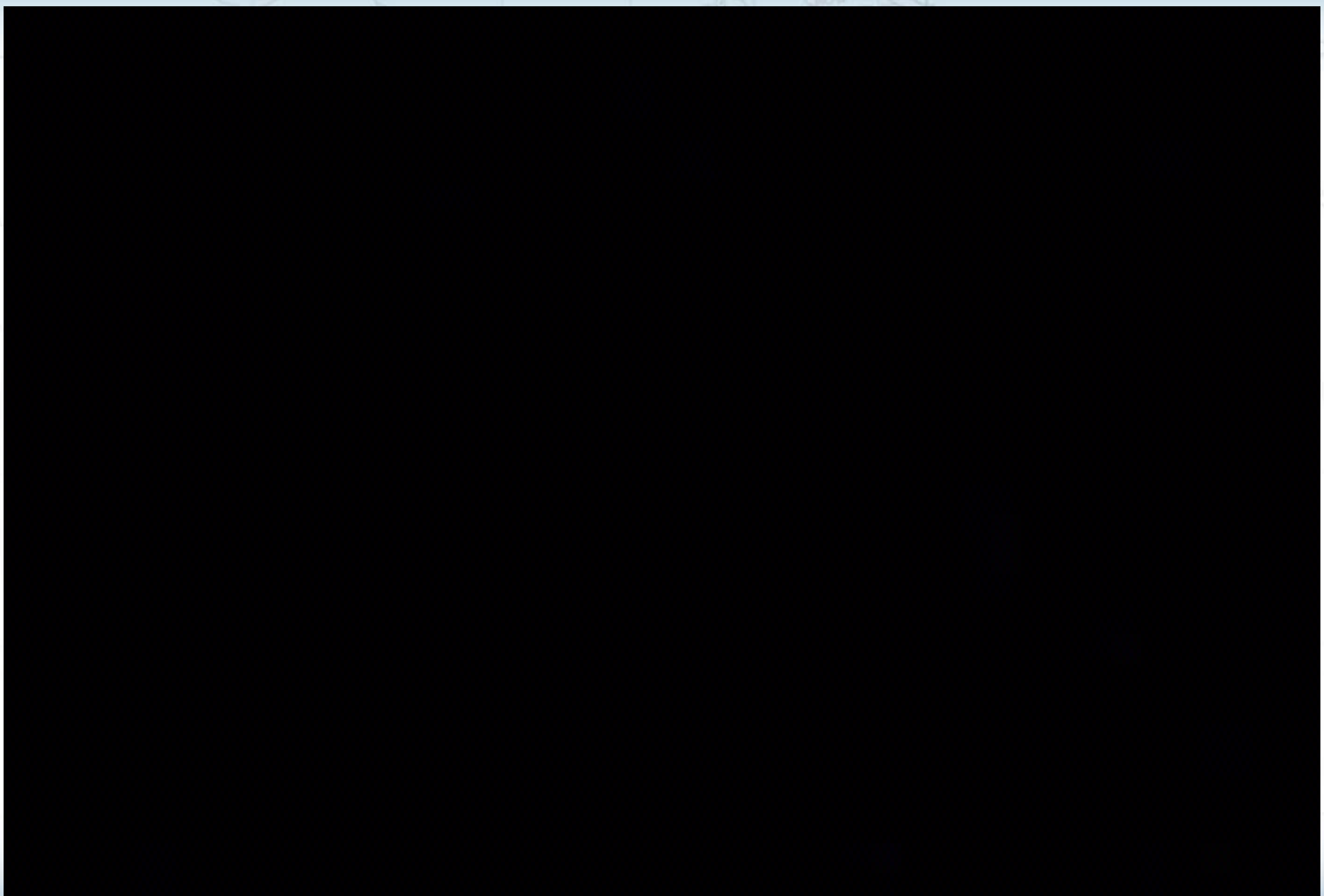
30mm x 113 Spotter Cartridge Testing at Fort Rucker

30mm x 113 Spotter Cartridge Testing at Fort Rucker: 1500m Day Impact

LAND SEA AIR

GENERAL DYNAMICS
Ordnance and Tactical Systems

30mm x 113 Spotter Cartridge Testing at Fort Rucker: 1500m Night Impact

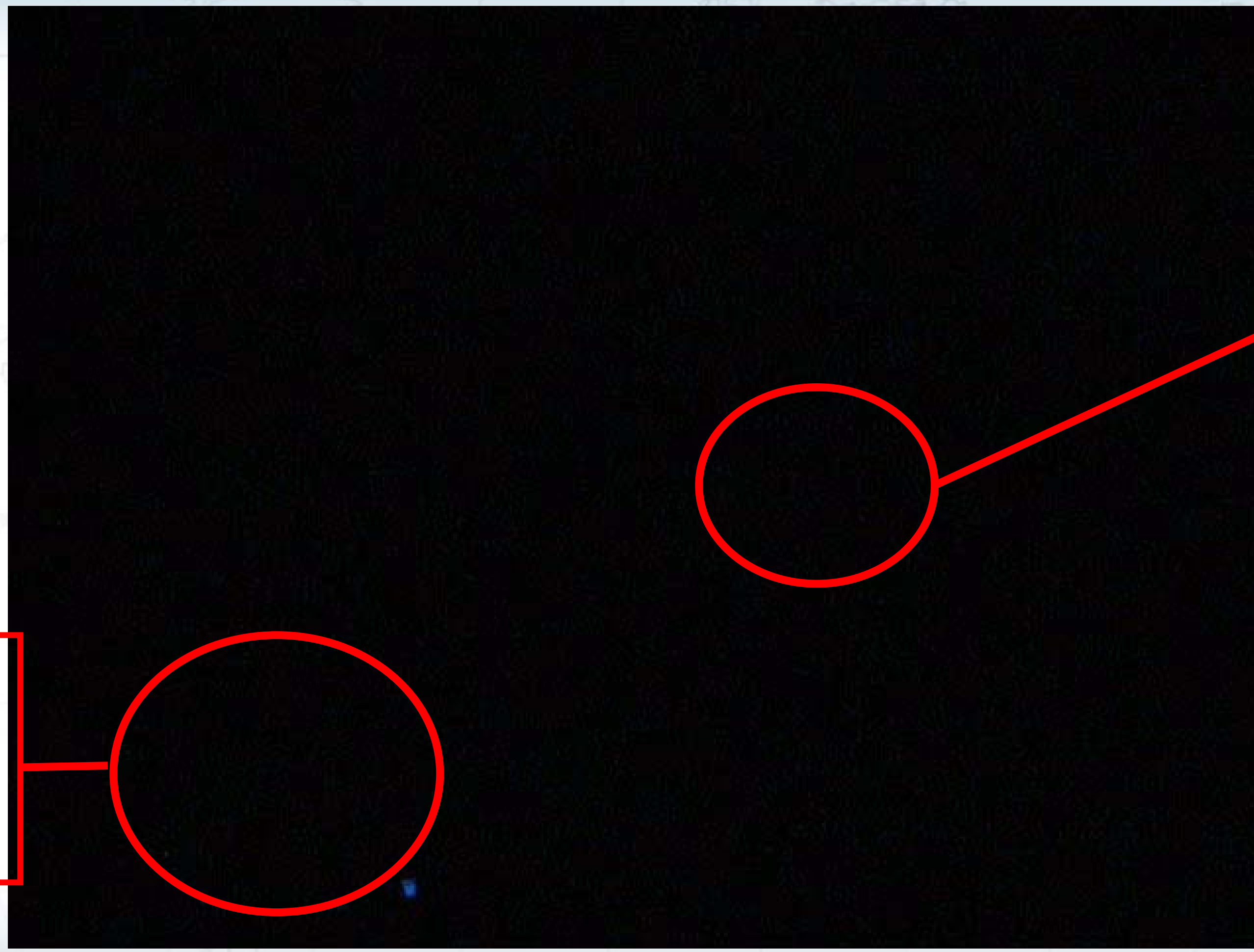


30mm x 113 Spotter Cartridge Testing at Fort Rucker: 1500m Day Target

White Steel Target at 1500m ~3.5sec Time of Flight

30mm x 113 Spotter Cartridge Testing at Fort Rucker: 3000m Night Target

Six Round Burst With One Impact



Steel Target at 3000m ~12sec Time of Flight

M230 Gun Position

30mm x 113 Target Practice Spotter Cartridge Safety Performance

40 Feet Drop Simulation: Air gun accelerated projectile with piston simulating cartridge mass for controlled velocity impact simulating drop from 40 feet

Pre-drop condition

Survives Extreme Drop Conditions and Is Safe to Handle

M230 Weapon Double Cartridge Feed Condition

Survives Double Ram Feed Loads in the M230 Gun System

Summary

30x113mm Target Practice Spotter cartridge:

- Is functional in the M230 automatic weapon
- Is a ballistic match to the 30x113mm cartridge family: M788 TP, M789 HEDP, PIE, and PIE-T
- Is designed using qualified components currently used in other production rounds such as: M788, PGU-28A/B and M940
- Has been demonstrated at 1500m and 3000m for the US Army at Fort Rucker in night and day conditions

30mm Spotter Cartridge is Operable in M230 Gun and Has Been Demonstrated for the US Army

Conclusion

GD-OTS is Ready to Produce for Current Needs or Develop for Future Apache AH-64 Needs

30mm x 113 Spotter Cartridge

Questions / Comments

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Scalable Air Burst Fuze Program

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Scalable Air Burst Fuze Overview

Since 2007, GD-OTS has been under contract with the US Army – Picatinny for the development of a scalable air burst fuze. Current focus is on fuze safety tests and demonstrations in the M242 and M230 weapons.

Air Burst Fuze Commonality for 25mm - 50mm Calibers

Scalable Air Burst Fuze Objectives

- Create an air burst fuze that is scalable for applications from 25mm through 50mm
- Perform Mil-Std-331 fuze safety tests
- Demonstrate fuze setting in the Bradley's M242 weapon fired at 200±25spm and Apache's M230 weapon fired at 625±25 spm
- Demonstrate airburst capability at various ranges using 25mm Bushmaster and 30mm Apache cartridges
- Develop selectable Point Detonate (PD) module for PD or PD delay capabilities
- Present airburst fuze design and test results to Army Fuze Safety Review Board

Scalable Air Burst Fuze –Safety Testing

MIL-STD-331 fuze safety tests were performed on the S&A device of the scalable air burst fuze

MIL-STD-331 Safety Test	Result
Transportation Vibration	Pass
1.5m Drop	Pass
Jolt	Pass
Jumble	Pass
Subverted Safety (setback lock omitted)	Pass
Subverted Safety (spin lock omitted)	Pass
Primary Explosive	Pass

Fuze Passes Key Safety Tests Ensuring Warfighter Safety

Scalable Air Burst Fuze – 2009 Development Testing

<table>
<tr><th>Description</th><th>Qty</th><th>Caliber</th><th>Standards</th></tr>
<tr><td>Transportation and Vibration</td><td>5</td><td>25mm</td><td rowspan="9">MIL-STD-331C</td></tr>
<tr><td>1.5m Drop</td><td>5</td><td>25mm</td></tr>
<tr><td>1.5m Drop (subverted setback)</td><td>5</td><td>25mm</td></tr>
<tr><td>1.5m Drop (subverted spin)</td><td>5</td><td>25mm</td></tr>
<tr><td>Primary Explosive Comp. Safety</td><td>15</td><td>30mm</td></tr>
<tr><td>Progressive Arming</td><td>20</td><td>30mm</td></tr>
<tr><td>ESD – Personnel Borne</td><td>5</td><td>30mm</td></tr>
<tr><td>ESD – Helicopter Borne</td><td>5</td><td>30mm</td></tr>
<tr><td>HERO</td><td>1</td><td>25mm</td></tr>
<tr><td>Aircraft Vibration</td><td>5</td><td>30mm</td><td rowspan="3">MIL-C-63982A</td></tr>
<tr><td>Normal Impact Function – PD</td><td>5</td><td>30mm</td></tr>
<tr><td>Normal Impact Function – PD Delay</td><td>5</td><td>30mm</td></tr>
</table>

A Multiple Caliber Air Burst Fuze
Ready for Demonstration

GENERAL DYNAMICS
Ordnance and Tactical Systems

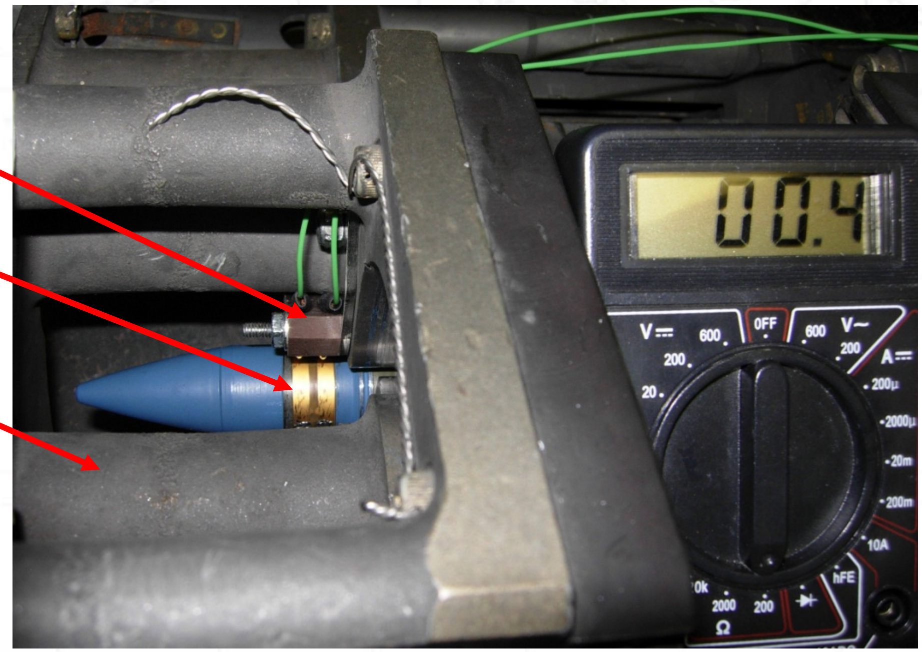
Scalable Air Burst Fuze – 25mm M242 Integration

GD-OTS successfully integrated fuze setting contacts into the 25mm M242 and demonstrated functionality at 200±25 spm.

Weapon contacts

Projectile contact bands

Weapon feeder



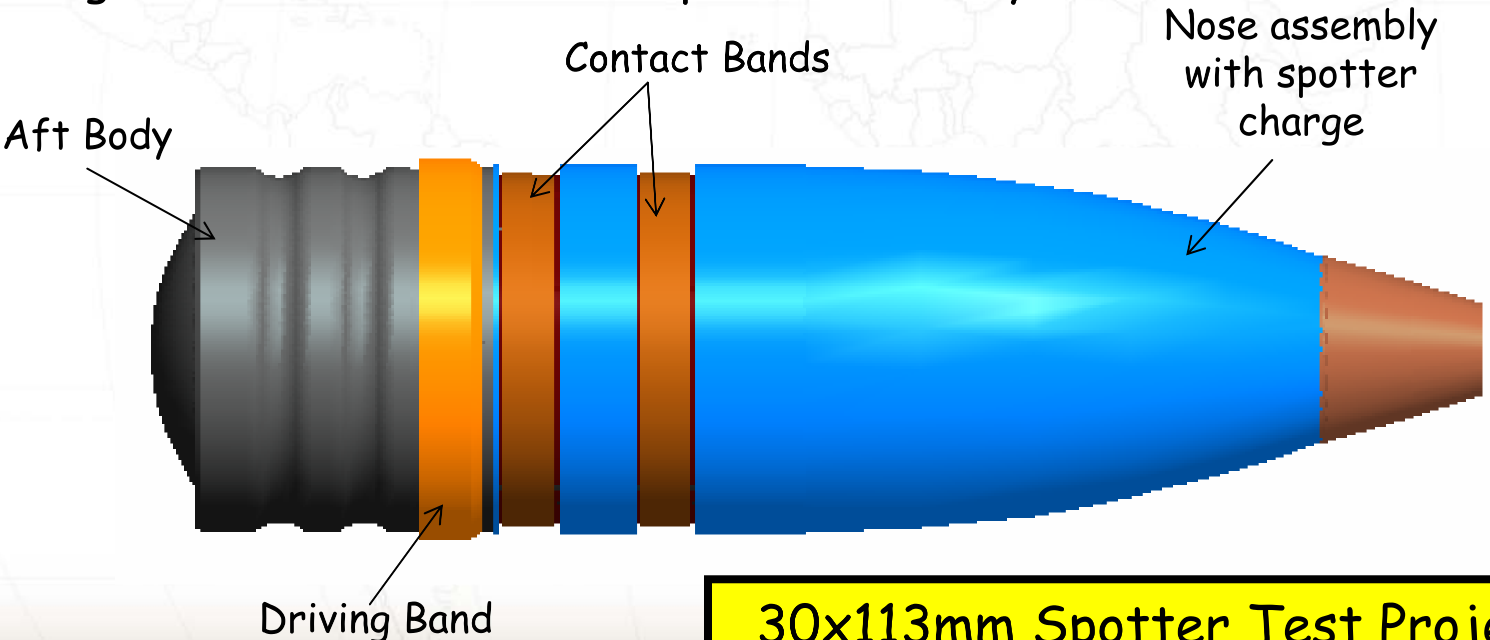
High Rate Burst of 200±25 Shots per Minute Demonstrated

Scalable Air Burst Fuze –25mm M242 Demonstration

Test Demonstration	Range	Qty	Objective	Status
Self-Destruct	2700m	5	Demonstrate capabilities vs. models & simulation	Scheduled for 4/2009
Burst Point Accuracy	600m, 1500m, 2500m	90	Demonstrate capabilities vs. models	Scheduled for 4/2009
M242 single shot & high rate bursts	1500m	32	Demonstrate capabilities vs. models	Scheduled for 4/2009

Scalable Air Burst Fuze – 30mm M230 Demonstration

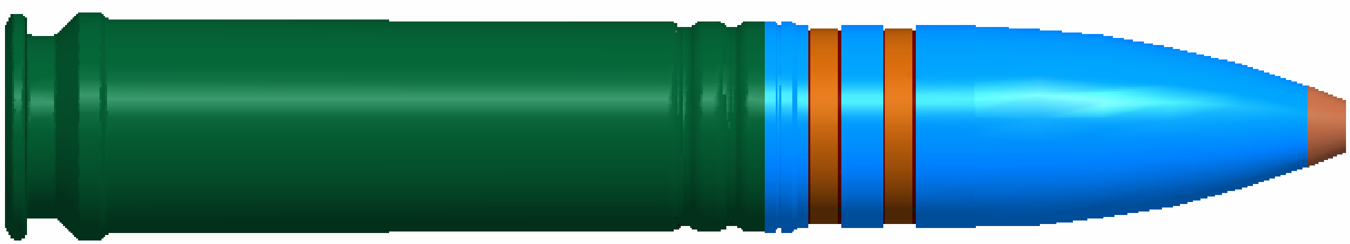
- 30x113mm test projectile has been designed
- Selectable PD/PD delay design is underway
- Integration into the M230 weapon is underway



30x113mm Spotter Test Projectile

Scalable Air Burst Fuze – 30mm M230 Technical Demonstration

Description	Quantity
Standard Point Detonation	5 rds at 200m
Point Detonation Delay	5 rds at 200m
Burst Point Accuracy	30 rds at 600m 30 rds at 1500m 30 rds at 3000m
M230 Single Shot	5 rds at 1500m
M230 Burst Shots (625spm using 5 rd bursts)	3ea 5 rd bursts at 1500m (single point) 3ea 5 rd bursts at 1500m (progressive) 3ea 5 rd bursts at 1500m (regressive)



Scalable Air Burst Fuze Capable of Firings at 625±25spm

Summary

- Fuze setting in M242 to function at high rate burst (200±25 spm) has been demonstrated
- S&A has passed Mil-Std-331 safety tests
- PD module with programmable delay will be tested in 30mm
- Integration of fuze setting contacts into M230 for function at high rate burst (625±25 spm) is in progress
- Fuze is scalable across calibers with similar integration across Bushmaster platforms
- Design incorporates U.S. Army Fuze Safety board guidance to assure soldier safety

Questions?

Raytheon
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Warship Upgrades to Utilize Modern Standard Missile

Newell (Butch) Young
Technical Director, Standard Missile
April 9, 2009

NAVAL WEAPON SYSTEMS

Introduction

Introduction

- The United States Navy deployed Standard Missile-1 (SM-1) on the Perry class FFGs; however, the missiles have since been removed
  - – U.S. Navy FFGs still retain the capability to launch SM-1
  - – The remaining FFGs will likely be sold/transferred over the next decade

- SM-1 continues to serve as the primary air defense missile system for Frigates (FFG) and Destroyers (DDG) of 11 International Navies

- Due to ship transfers and International Navy requirements, FFGs and DDGs that utilize SM-1 will remain in service beyond the lifespan of the missile

NAVAL WEAPON SYSTEMS

What can Navies do to retain AAW capability?

SM-1 Shooters Today

- DDG
  - Chile
  - France
  - Italy
  - Japan
- FFG
  - *Australia
  - Bahrain
  - Egypt
  - Poland
  - Spain
  - Taiwan
  - Turkey

*Australia is currently upgrading FFGs to SM-2

SM-1 Overview

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Missile Systems

- All-weather, ship-launched, medium range, fleet air defense missile system
- Provides significant capability
  – Semi-active radar
  – Anti-ship cruise missiles
  – Aircraft
  – Helicopters
  – Rail launch (MK 13/26)
- Range > 46 km
- Altitude Up to 24 km
- Velocity > Mach 2.0

NWS
NAVAL WEAPON SYSTEMS

SM-1 Shooters

Provide these warships with enhanced air defense

Customer Success Is Our Mission

Steps to Upgrade the Ship

FFG Upgrade Approach

- FFGs utilize several different Combat Management Systems (CMS)
  – MK 92 Mod 2
  – MK 92 Mod 6
  – MK 92 Mod 12
- Mod 2 Requirements:
  – Digital Initialization (Standard Missile Adjunct Processor)
  – Launcher Ordalt (ablative and electrical mods)
  – Employ in Home-All-The-Way (HAW)
  – Reliability and upgraded capabilities addressed
  – Improved SM-2 performance within the SM-1+ boundary (simplifies Weapon System modifications)

FFG Mod 6/12 & DDG Upgrade Approach

Raytheon Missile Systems

- MK 92 Mod 6/12 CMS offer greater capabilities than Mod 2
- DDGs have more powerful CMS and shipboard systems
- To upgrade MK 92 Mod 6/12 or DDG requires same minimum changes as Mod 2 and the following
  - MK 13 Launcher Ordalts (ablative)
  - Illuminator noise upgrade
  - SM-2 Adjunct Processor (SMAP)
  - Employ in HAW mode
  - Improved exploitation of ship system capability
- OR Same as Mod 2, Plus
  - Add improved INS
  - Add uplink capability (OT 134 or SSTx)
  - Procure new Block IIIA missile's
  - Employ in HAW and Midcourse (MCG)
  - Exploit SM-2 to its maximum capacity, constrained only by ship system capabilities

NWS NAVAL WEAPON SYSTEMS

System Upgrades for HAW

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Missile Systems

- Minimum system upgrade for SM-2 limits modifications
  - AM/FM Open Architecture (OA) modifications to legacy Continuous Wave Illumination (CWI) transmitters
  - Full OA to MK 13
  - Standard Missile Adjunct Processor (SMAP) for SM-2 initialization minimizes impact on existing infrastructure and SM-2 Weapon Control Software (WCS)
    - Utilizes engageability and scheduling processes in WCS that are similar to SM-1
    - Detection, tracking and engagement is limited to SM-1 envelopment and ship capabilities (radars, CMS)
      - Enhanced performance within parameters
    - Minimum modifications to MK 92 or DDG FCS and command and control software

NWS NAVAL WEAPON SYSTEMS

System Approach for MCG

Raytheon Missile Systems

- Basic upgrades for HAW are needed
- Additional modifications include
  - Improved Inertial Navigation System
  - OT-134 or solid state transmitter with uplink capability
  - Additional integration between SMAP and WCS to enable engagement at extended ranges

NWS NAVAL WEAPON SYSTEMS

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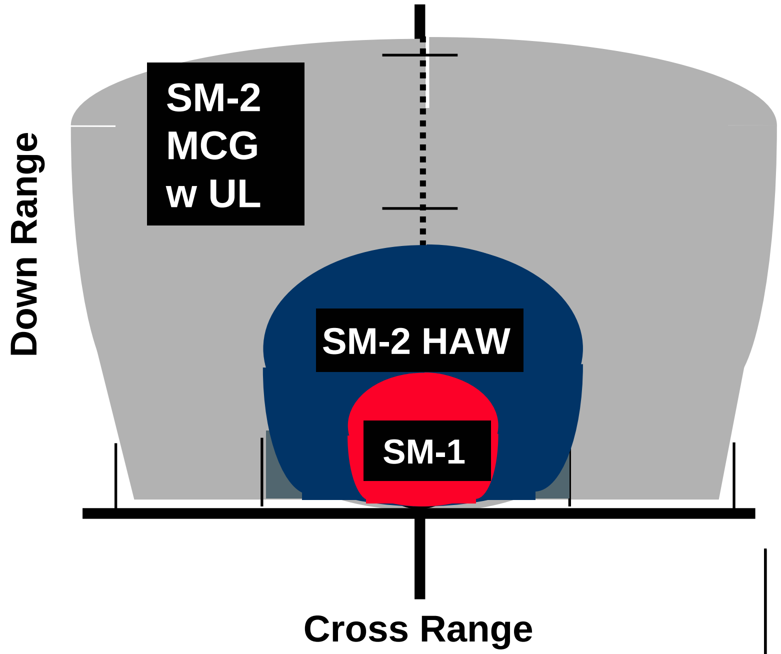
Benefits of Upgrading the Ship

SM-2 Block III/IIIA

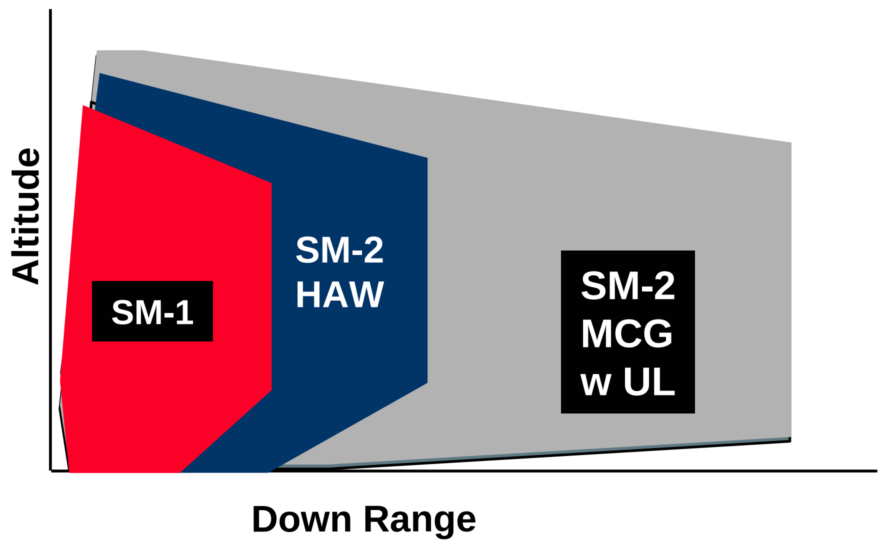
- All-weather, ship-launched, medium-to-long range, fleet/area air defense missile system
- Provides significant capability
  - Monopulse, solid state, semi-active radar
  - Midcourse guidance
  - Extreme low altitude ASCM
  - High altitude cruise and diver
  - ECCM
  - Helo
  - Vertical (MK 41) or rail (MK 13)
- Range > 80 km
- Altitude > 65,000 ft (>20 km)
- Velocity > Mach 3

SM-1 vs. SM-2 Engagement Envelope



Notes:

- SM-2 HAW boundaries are notional
- SM-2 MCG boundaries are notional



Key Benefits

- SM-2 has numerous improvements over SM-1
  - Greater target detection capability due to improved seeker and Target Detection Device
  - Increase kinematic capabilities and superior maneuverability
  - Greater engagement envelope and defended area
    - MCG provides greater footprint than HAW
  - SM-2 is in use by the U.S. Navy and 7 International Navies (Currently), which enables better logistics support for a longer period of time
- Upgraded ship performance
  - Improved detection, track and engagement capabilities resulting from radar and CMS modifications

Conclusion

Summary

- Some FFGs and DDGs will remain in service beyond the lifespan of SM-1
- Ships upgraded to SM-2 will have increased capability and performance
- Ship upgrades to enable the firing of SM-2 are a low-cost solution that keep the ship and crew defended against the threats of today and tomorrow

Raytheon
Customer Success Is Our Mission

Presentation to 44th Annual Guns & Missiles Conference

Evolving Artillery Operational Concepts from Guided Projectiles

Chris E Geswender
cegeswender@raytheon.com
David Brockway
dabrockway@raytheon.com

April 23, 2009

NOTE – All equations, weapon descriptions, and equipment specific materials are from open sources, usually the internet to avoid ITARS or classification issues

Need for Guided Projectiles-Operational

Raytheon
Missile Systems

- The Air Force and Navy aircraft tend to be more suited to Operational Support vs Close Air Support
  - Operational level targets are more valuable
  - CAS targets age out before response
  - “Broken Arrow” changes everything

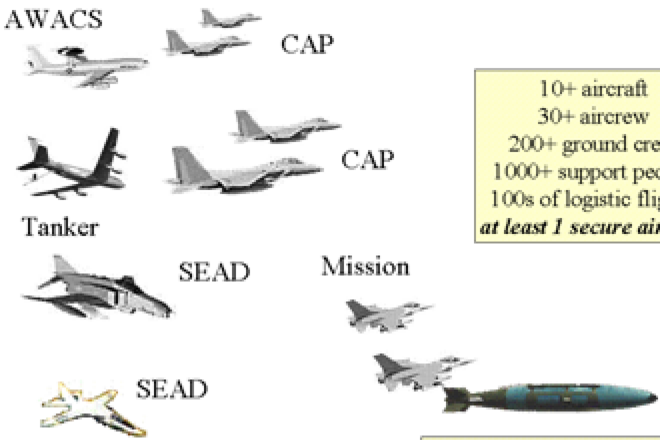
- Army must fight 24/7 once engaged - all weather and does not have the luxury of weather “down times”
  - **Battle of the Bulge 1944** - enemy exploitation of loss of air power
  - Time to call in support needs to be “immediate” in many cases
  - Response timeline may not allow bringing to bear the full air might
  - Some places just can’t get air support easily

The Army that can deliver overwhelming force in the shorter time will break the enemies will to resist - guided projectiles provides an army on the ground with the stand off precision heretofore only available from air forces

Cost to Delivery “First” Precision Weapon

Raytheon Missile Systems

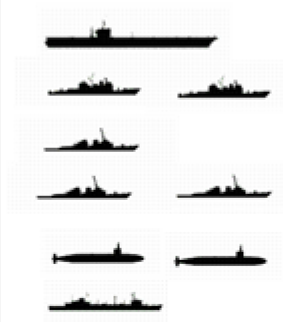
USAF



10+ aircraft
30+ aircrew
200+ ground crew
1000+ support people
100s of logistic flights
at least 1 secure airfield

First Bomb ~ $14B

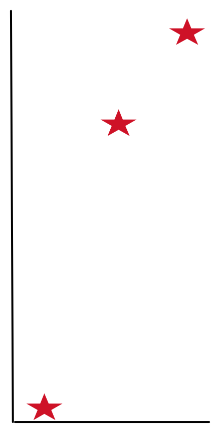
USN



	Cost	Men	Planes	Weapons
a carrier –	$4.5B	5,680	~$4B	~$500M
two guided missile cruisers –	$2B	730	$24M	$100M
a guided missile destroyer – AAW	$.8B	323	$12M	$50M
2 destroyers – ASW	$1.6B	646	$24M	$100M
two attack submarines	$4B	270		$50M
a combined ammunition, oiler, and supply ship	$.5B	667	$15M	$10M
	$13,5B	8316		$800M

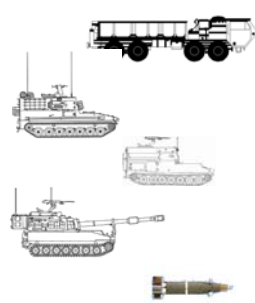
First Bomb ~ $20B

- Cost to deliver Precision varies dramatically as cost and required types of platforms to execute mission considered
- WOT vs. NPW cost calculus



USA

Cost of first projectile ~ $59M



	Cost	Men	Weapons
5x HEMMT truck	$1.0M	10	
1x M992A2 Fire Direction Center Vehicle (FDCV)	$2.0M	5	
6xM992A2 FAASV Field Artillery Ammunition Supply Vehicle	$6.6M	24	
6x M109A6 Paladin Self Propelled Howitzer	$9.6M	24	
M982 Excalibur Basic Load			$40M
	$19.2M	63	$40M

Cost per Kill

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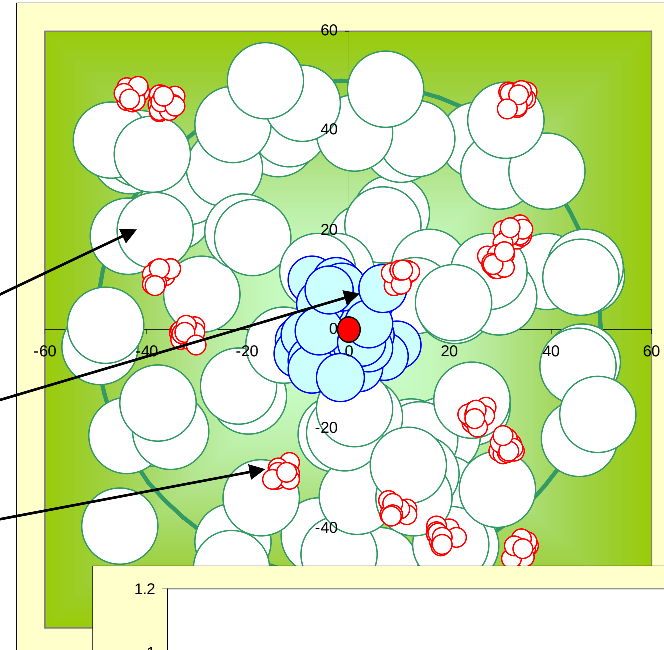
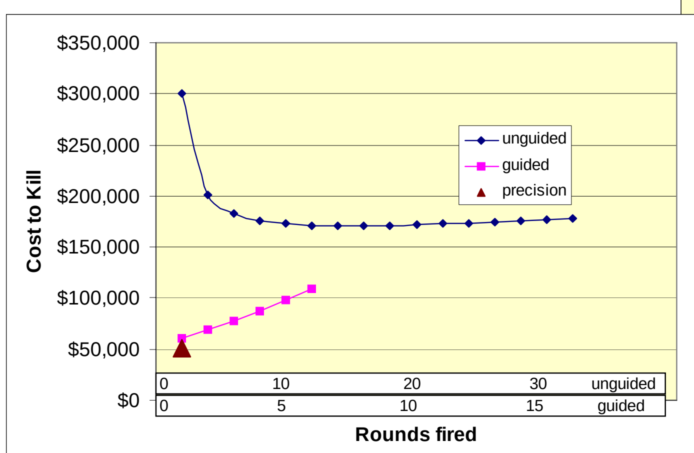
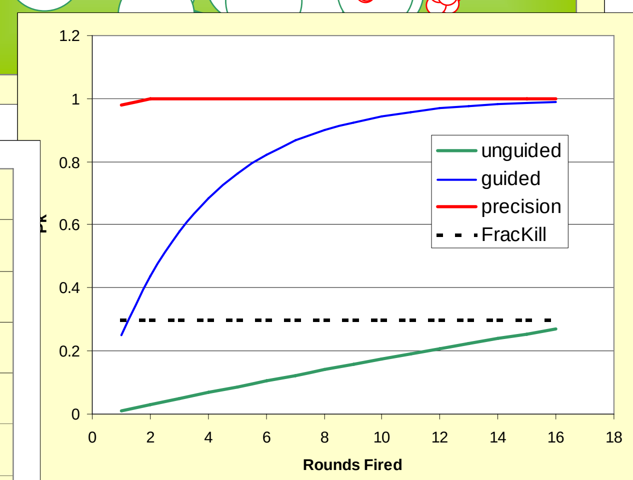
Missile Systems

Assume a scenario of an area target and attack the center of the area using either:
unguided projectiles
guided projectile
Terminally guided projectiles



The cheapest projectile does not result in the cheapest kill





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Missile Systems

What is Cost? How do you Measure it?

	USA	USAF	USN
■ Weapon Acquisition Cost	1.0	1.0	1.0
■ Life Cycle Cost	2.0	2.5	2.5
■ Cost per kill	8.0	10.0	10.0
■ Attrition Adjusted Cost	8.1	13.0	13.0
■ Campaign Cost	8100	21100	21100
■ "Opportunity" Cost	<5 min	<30 min	<30 min

With the employment of precision weaponry, the homily "when seconds count, the police are minutes away" is appropriate in looking at costs

Fire Support Priorities (Ranked)

1. Precision *(Accuracy)*
2. Responsiveness *(Tempo)*
3. Mobility *(Logistics)*
4. Range

(See the "State of the Field Artillery 2007" by MG Vangjel in the September-December 2007 *Fires*.)

Major Factors in Change in Employment

Raytheon
Missile Systems

- Accuracy –
  - Specific targets rather than area
  - Reduce the number of rounds fired required to execute the mission
  - Reduce cost to execute the mission
- Tempo –
  - Fewer rounds means more missions executed in any time period
  - Operational tempo means shorter campaign
  - Shorter mission time reduces exposure to the counter fire threat
  - Ability to provide precision supporting fire allows rapid transition from fires to assault
- Logistics –
  - Fewer rounds reduces direct logistics train to support battery
  - Shorter campaigns reduces the indirect logistics train required to provide support personnel

Accuracy – New Missions

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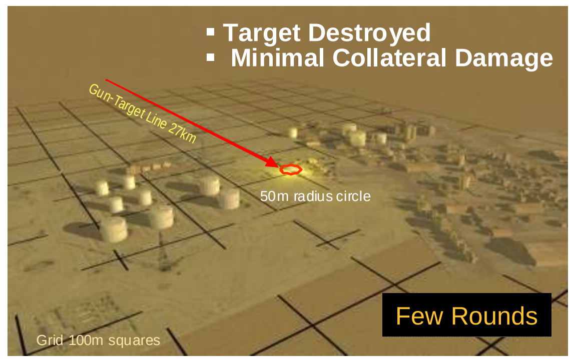
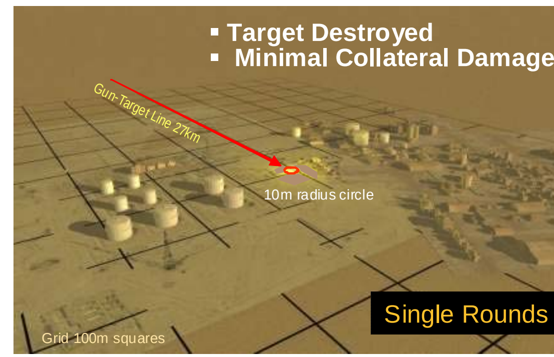
Missile Systems

Today's Capability:
183m CEP*

PGK:
≤50m CEP



EXCALIBUR:
≤10m CEP



* **M109A6 (Paladin) at 27km: 155mm (HE) M549A1**

- **Improves Munition Accuracy**
  - **Faster Deployment – Fewer Unit to Ship**
  - **Improved Cost Per Kill**
  - **Faster Mission Response Time**
- **Greatly Reduces Possibility of Collateral Damage**
  - **New Missions for Artillery**
  - **Organic Precision for Engaged Small Units**
- **Increases Number of Kills per Basic Load of Ammunition**
  - **Faster OPTEMP**
  - **Smaller Logistics Tail**

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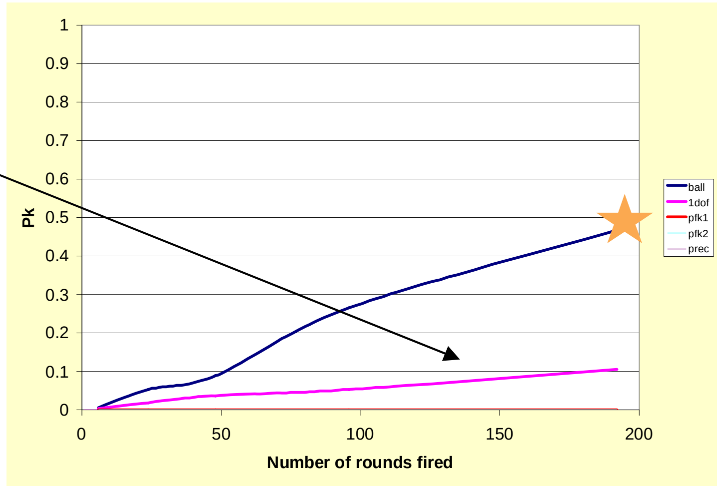
Missile Systems

Accuracy - Fewer rounds per mission

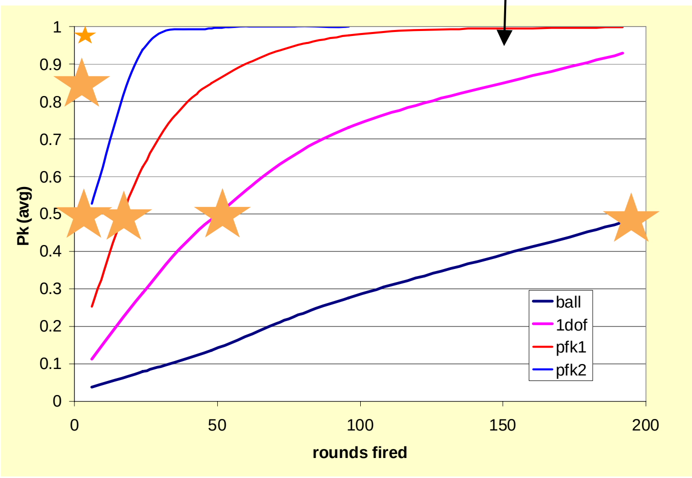
= Number of rounds to execute mission

- Precision does not help against areas targets using a single center aimpoint
- Precision helps against area targets with smart sheafing, but precise accuracy isn't as important
- Precision helps against a single target and improved accuracy does help

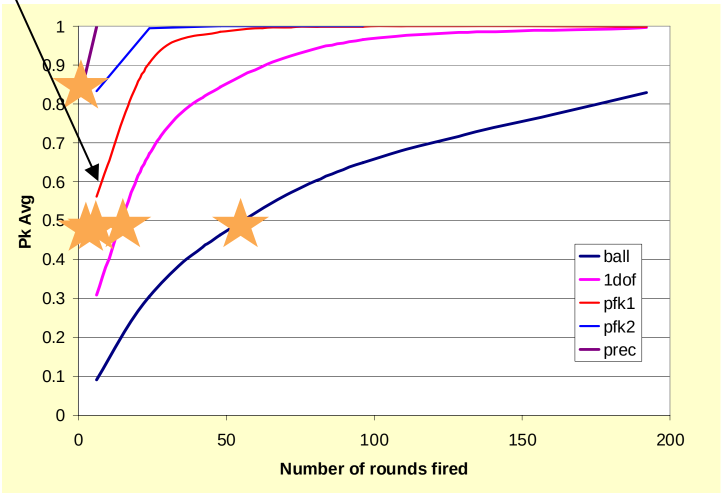
Multiple Targets – Center Aimpoint



Single Target



Multiple Targets - Sheafed

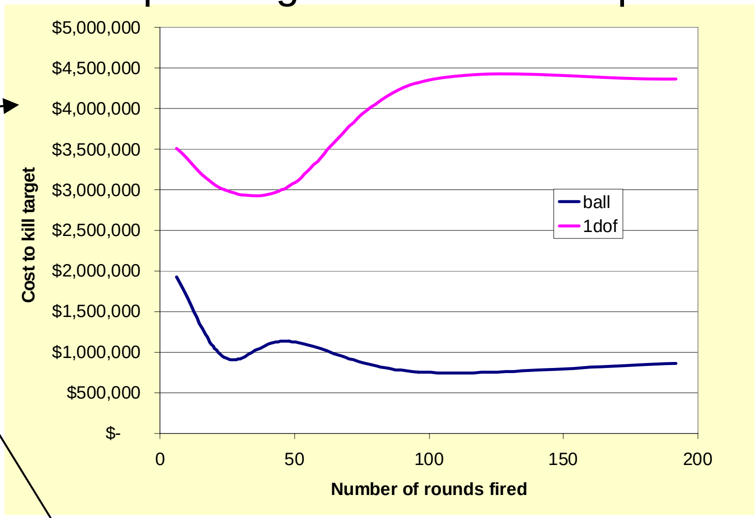


Accuracy – Lower Cost to Execute a Mission

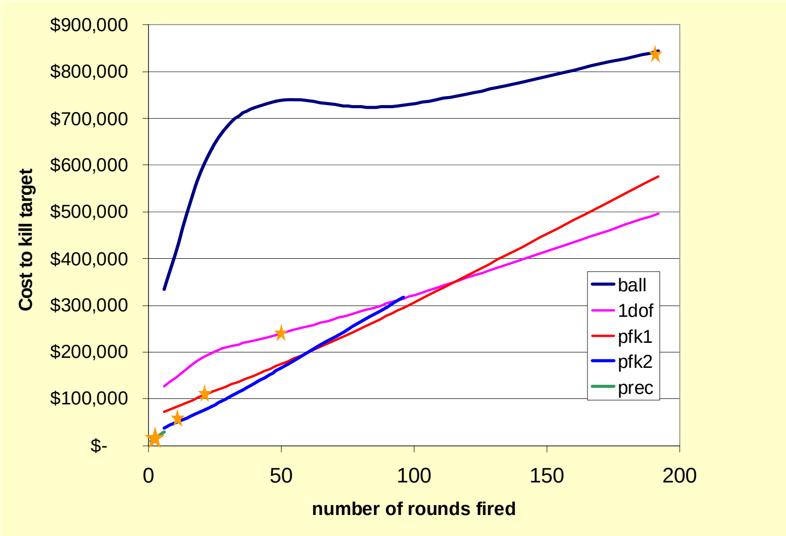
★ =cost to execute mission

- Precision does not help against areas targets using a single center aimpoint
- Precision helps against area targets with smart sheafing, but precise accuracy isn't as important
- Precision helps against a single target and improved accuracy does help

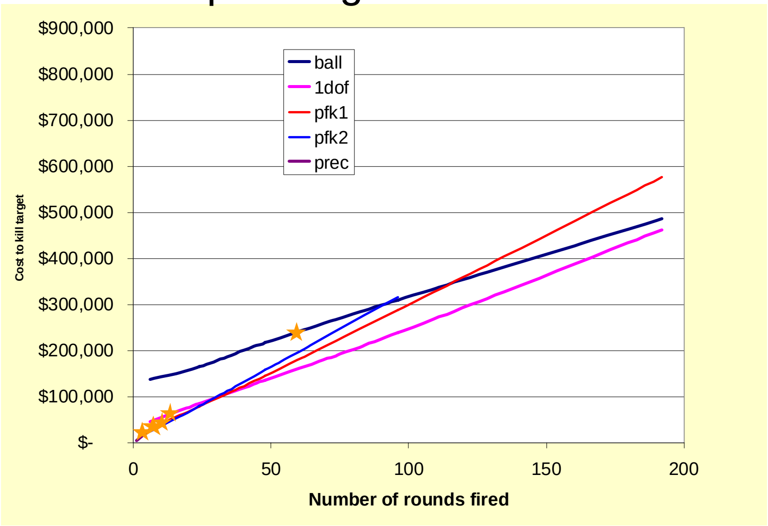
Multiple Targets – Center Aimpoint



Single Target



Multiple Targets - Sheafed



Precision - Also Provides Tempo

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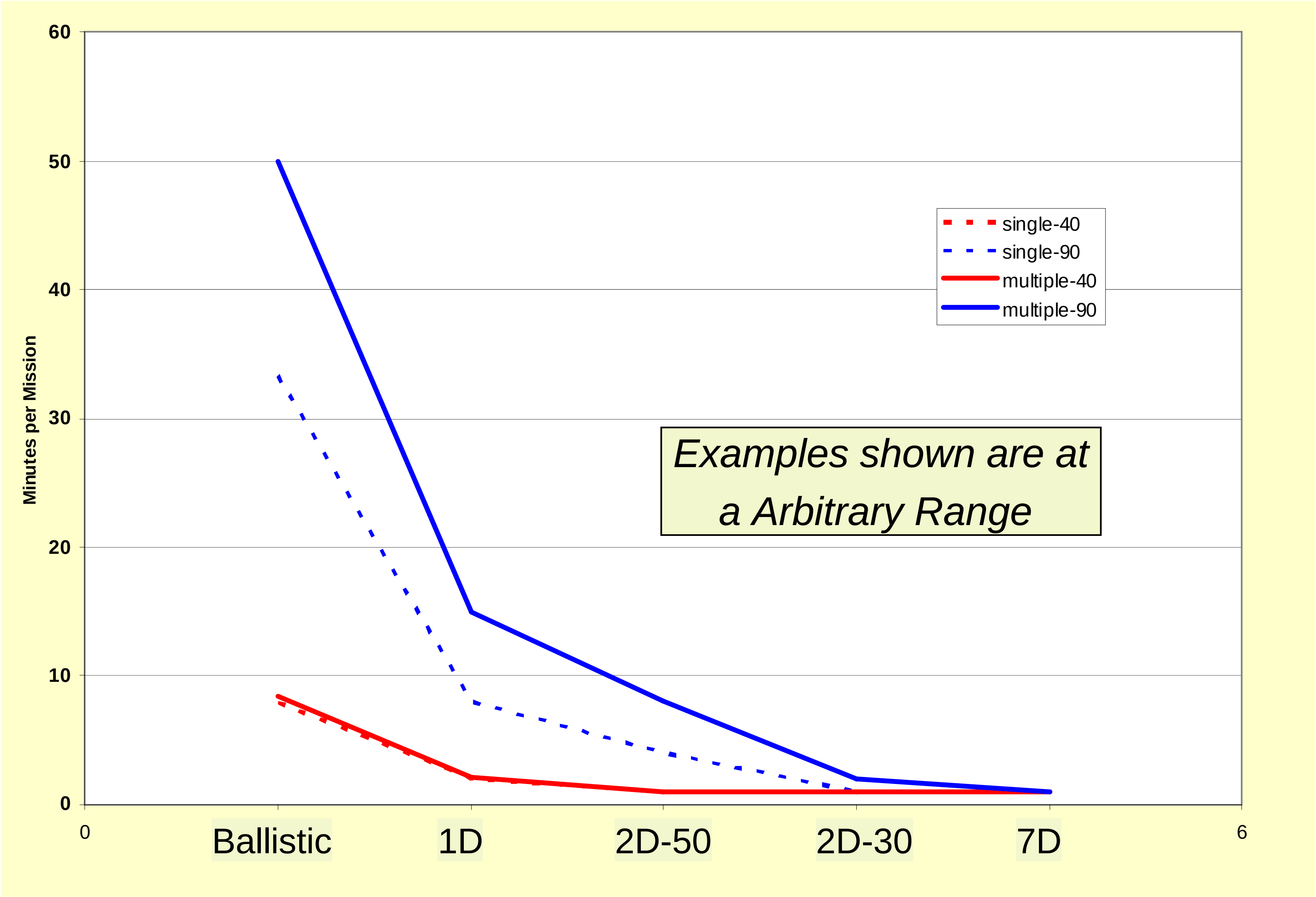
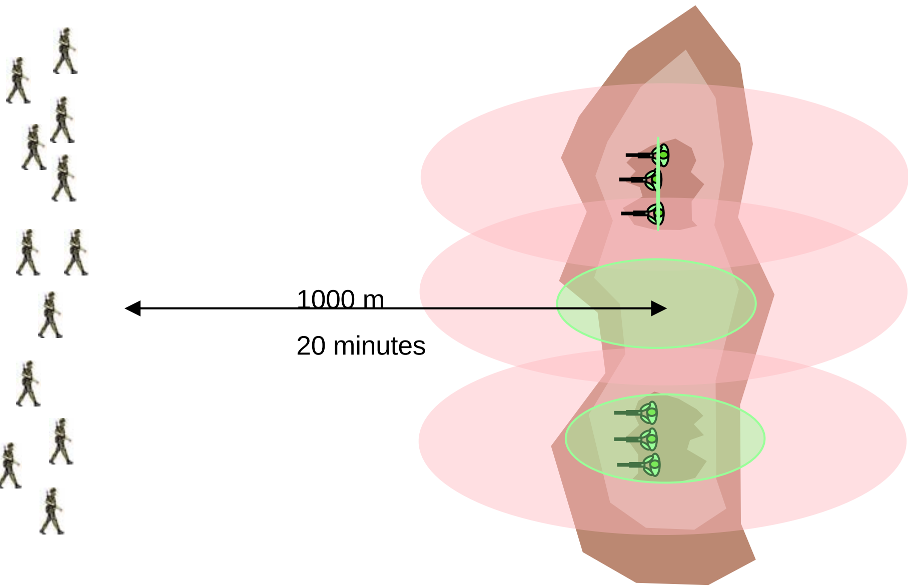
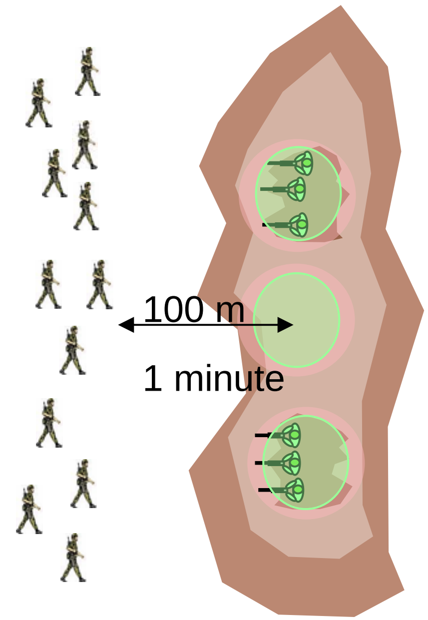
Missile Systems



Tempo - Open Area Assault





Artillery prepares for assault by infantry
Mission requires infantry to complete
Artillery must be lifted 20 minutes before assault
Infantry advances against defensive fire

Artillery prepares for assault by infantry
Mission requires infantry to complete
Artillery lifted seconds before assault
Infantry advances before defensive fire reestablished

Artillery is now an integral part of the assault rather than preparation to assault

Tempo - Urban Operations

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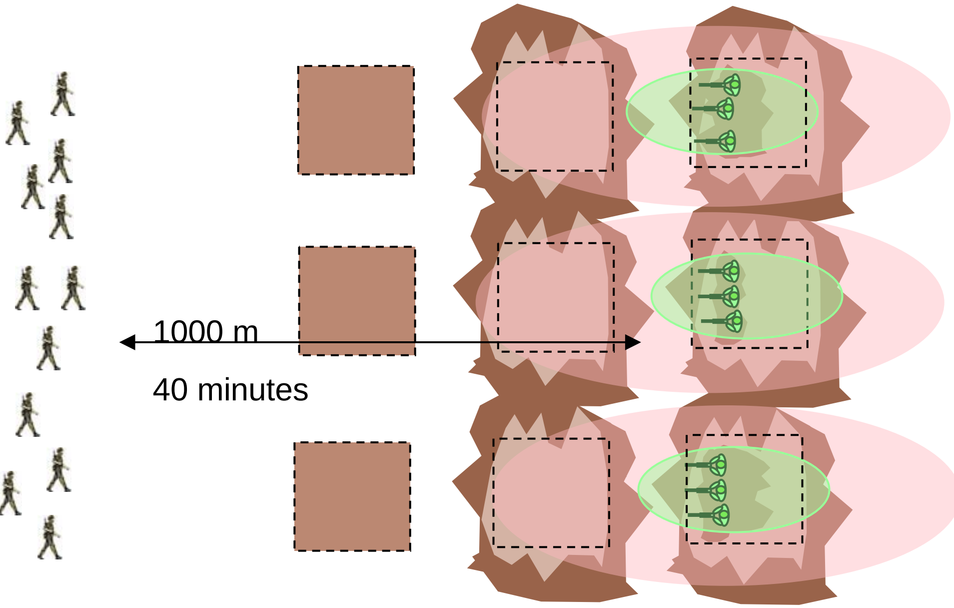
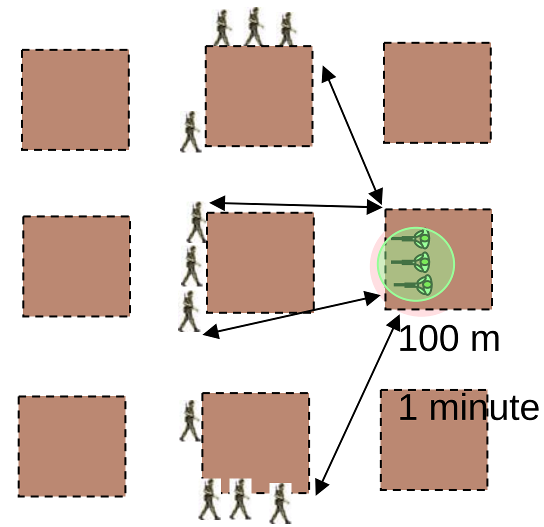
Missile Systems



Artillery prepares for assault by infantry
Mission requires infantry to complete
Artillery must be lifted 20 minutes before assault
Infantry advances into ***rubble against*** *effective defensive fire*

"STALINGRAD"

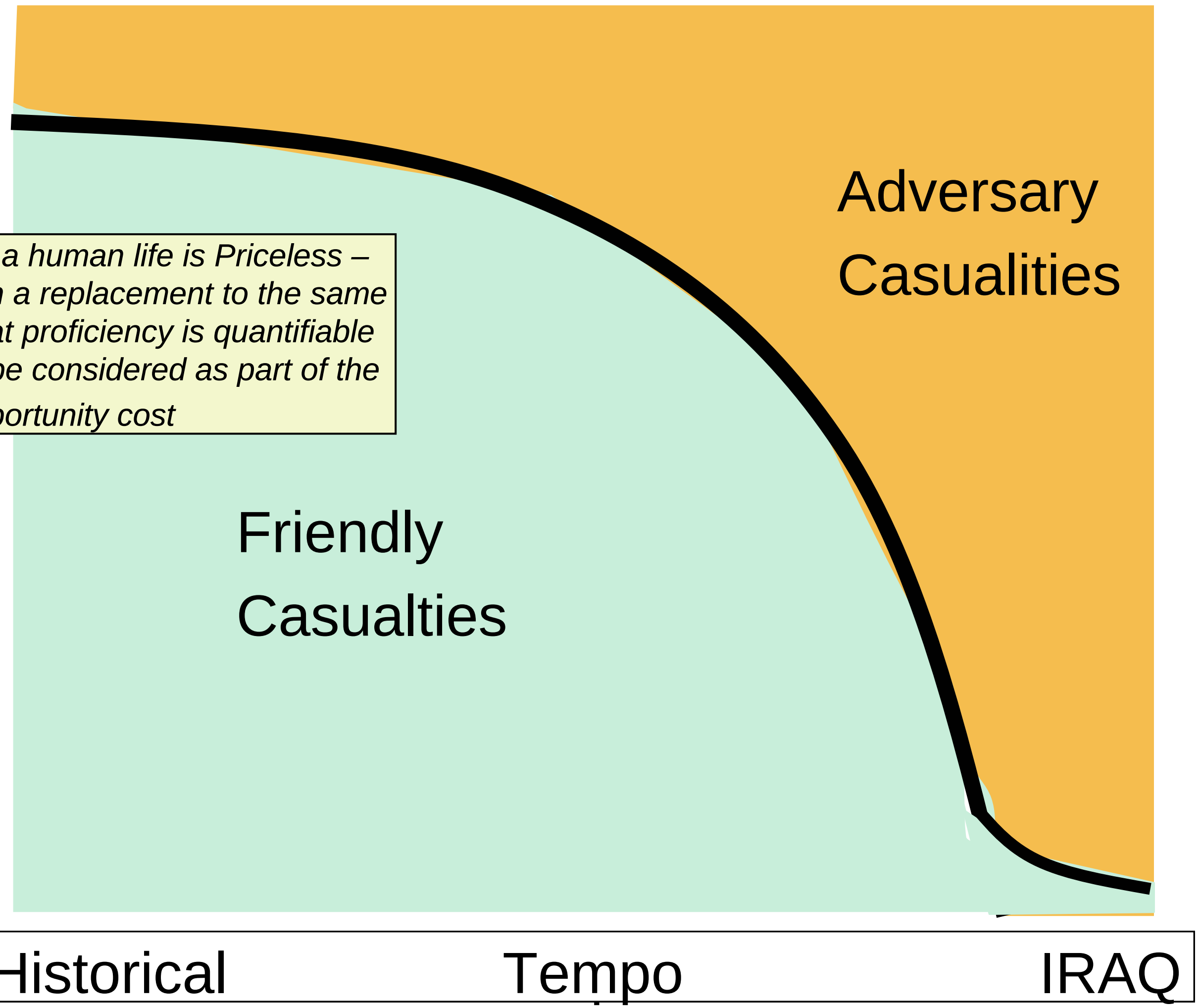


Infantry advances until hostiles engage from building
Artillery fired at building, until fire suppressed
Infantry ***clears objective****, proceeds*

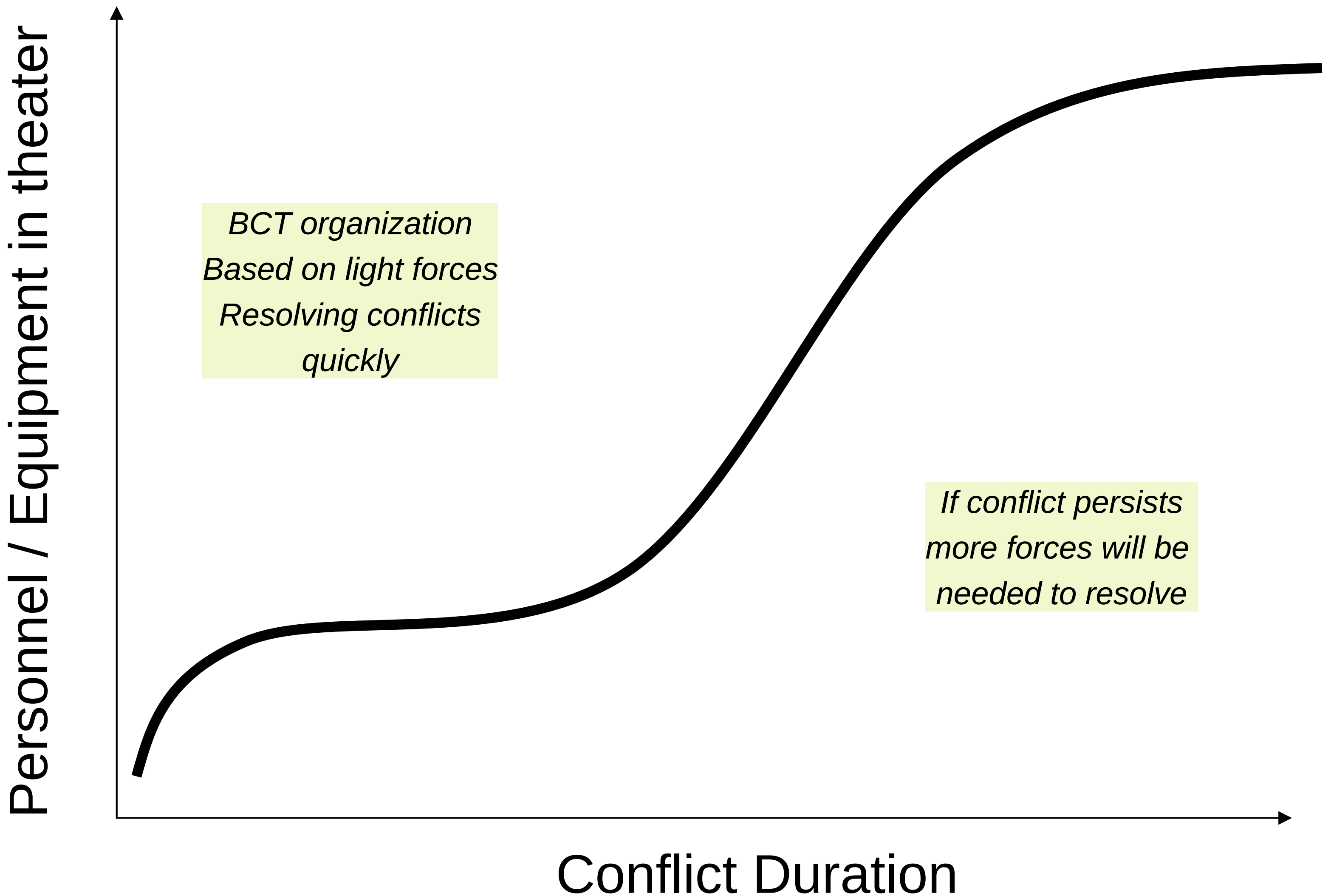
"BAGDAD"

Tempo – Improved exchange ratios

While the cost of a human life is Priceless – the cost to train a replacement to the same level of combat proficiency is quantifiable and needs to be considered as part of the opportunity cost



Tempo – Will effect Logistics need



Logistics - Demands increases rapidly as combat duration grows

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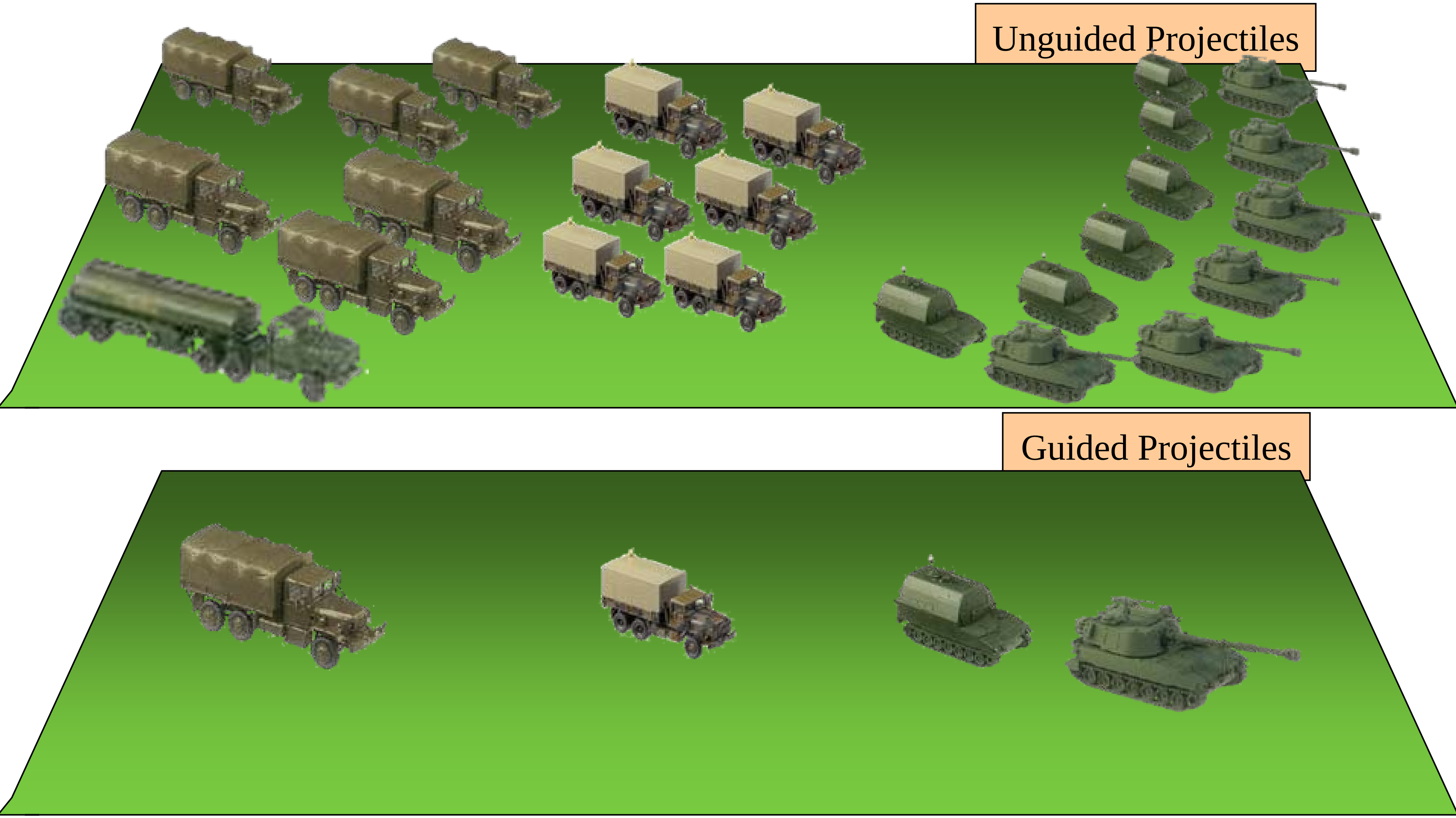
Missile Systems

Logistics - The True Cost of a Projectile Mission

Raytheon Missile Systems



Logistics – Support logistics dominates combat logistics

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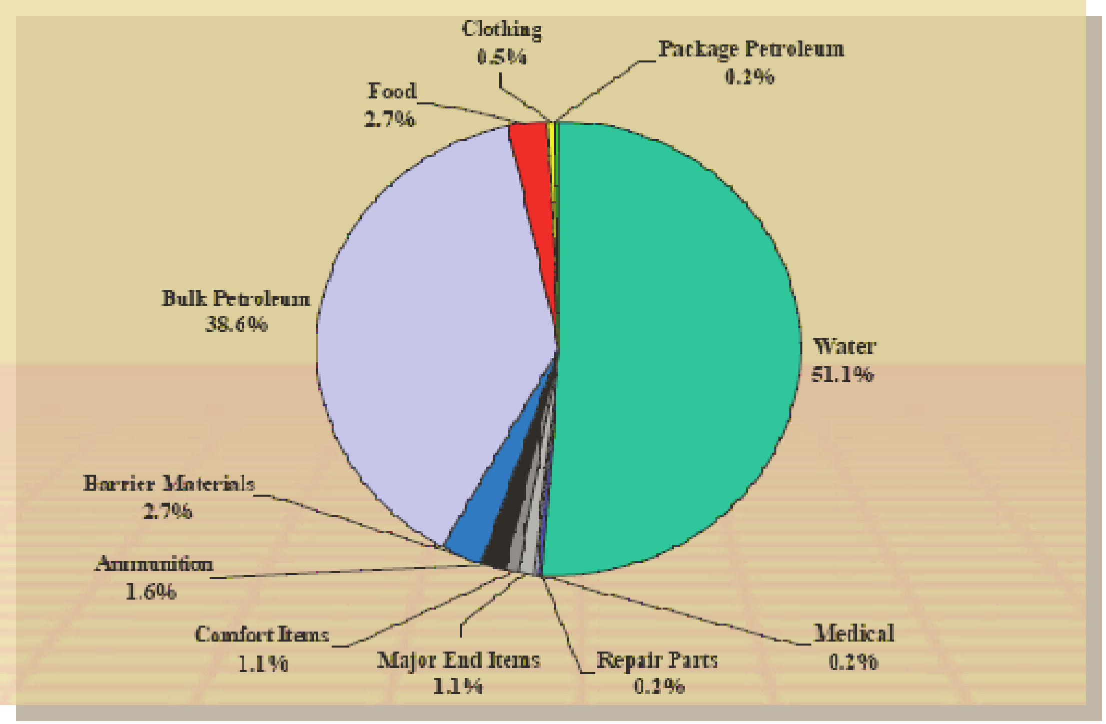

Water/ petroleum	~ 90%	(90% to support)
Combat (ammunition, barrier, medical, repair)	~ 5%	
Other	~ 5%	(90% to support)

Only 15% of Logistics is "direct" support

Raytheon Missile Systems

SUMMARY

- Precision
  - Faster destruction of target
  - Less Collateral Damage
  - Reduction of rubble defensive positions
- Delivery Control
  - Multiple mission capability
  - Less Collateral Damage
  - Mission Responsive Ordnance activities
- Reliability
  - Reduced logistics tail
  - Less Collateral Damage
- Design Flexibility
  - Multiple Gun capability
  - Seeker / Hard Kill Variants
  - Payload evolution (Inherent PIP)

Precision is good in itself, but the major operational benefits are that the logistics reduction and that reduced time to complete mission greatly increases operational tempo and reduces friendly casualties

Gun Propellants For The 27 mm Cal. Gun Eurofighter Jet

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44th Annual Gun & Missile Systems Conference & Exhibition

April 6 - 9, 2009

Kansas City, Mo, U.S.A.

Fraunhofer Institut Chemische Technologie

DIEHL BGT Defence

Content

- Introduction
- DNDA - Propellants
  - Thermodynamic Characteristics
  - Temperature Behaviour of LTC Propellant in Closed Vessel
  - Performance, Safety Test Results
  - Sensitivity Data DNDA - Propellants
  - Shaped Charge Tests
  - Erosivity
- Gun Firing
  - 75 mm cal. Propellant Charges (2 LTC Propellants)
  - 27 mm cal. Eurofighter (EF) Propellant Charges
- EF Propellant 27 mm cal. for PELE Ammunition
- PELE Ammunition Concept
- Results & Conclusion

Introduction

Since approx. 100 years are known the Nitrocellulose Propellants

Self - Ignition Temperature ~ 175 °C

Also the Multi Base Propellants like SCDB and EI, ECL Propellants are

giving the Self - Ignition at ~ 175 °C

Nitrocellulose Propellants based on DNDA and RDX the

LTC Propellants are showing

- First Generation

  Self - Ignition Temperature 200 - 210 °C

- Second Generation

  Self - Ignition Temperature > 220 °C (Eurofighter Propellant etc.)

DNDA Gun Propellants

- RDX
- Binder, Nitrocellulose
- DNDA Plasticizer

✳ Plasticizer mixed into the Propellant - Dough

NO SURFACE COATING

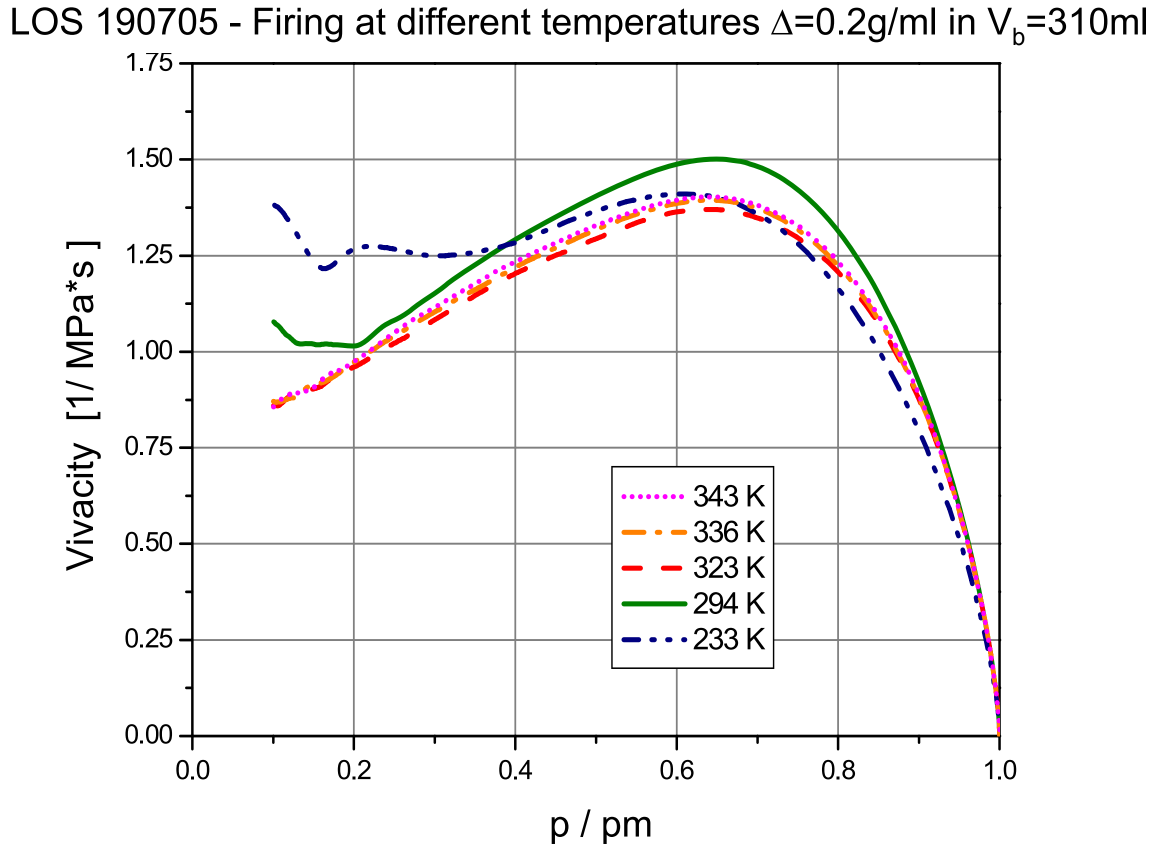
- energy density adaptable
- flame temperature approx. 500 K lower compared to NC Propellants

Formulation	*Impetus (J/g)*	*Flame Temp (K)*	*$\overline{M}w$ (g/mole)*
A	*1080*	*2540*	*19.4*
B	*1180*	*2910*	*20.8*
C	*1300*	*3390*	*21.6*

Closed Vessel Behaviour of LTC Propellants

Vivacity of Gun Propellant based on DNDA

Range -40 °C till +70 °C



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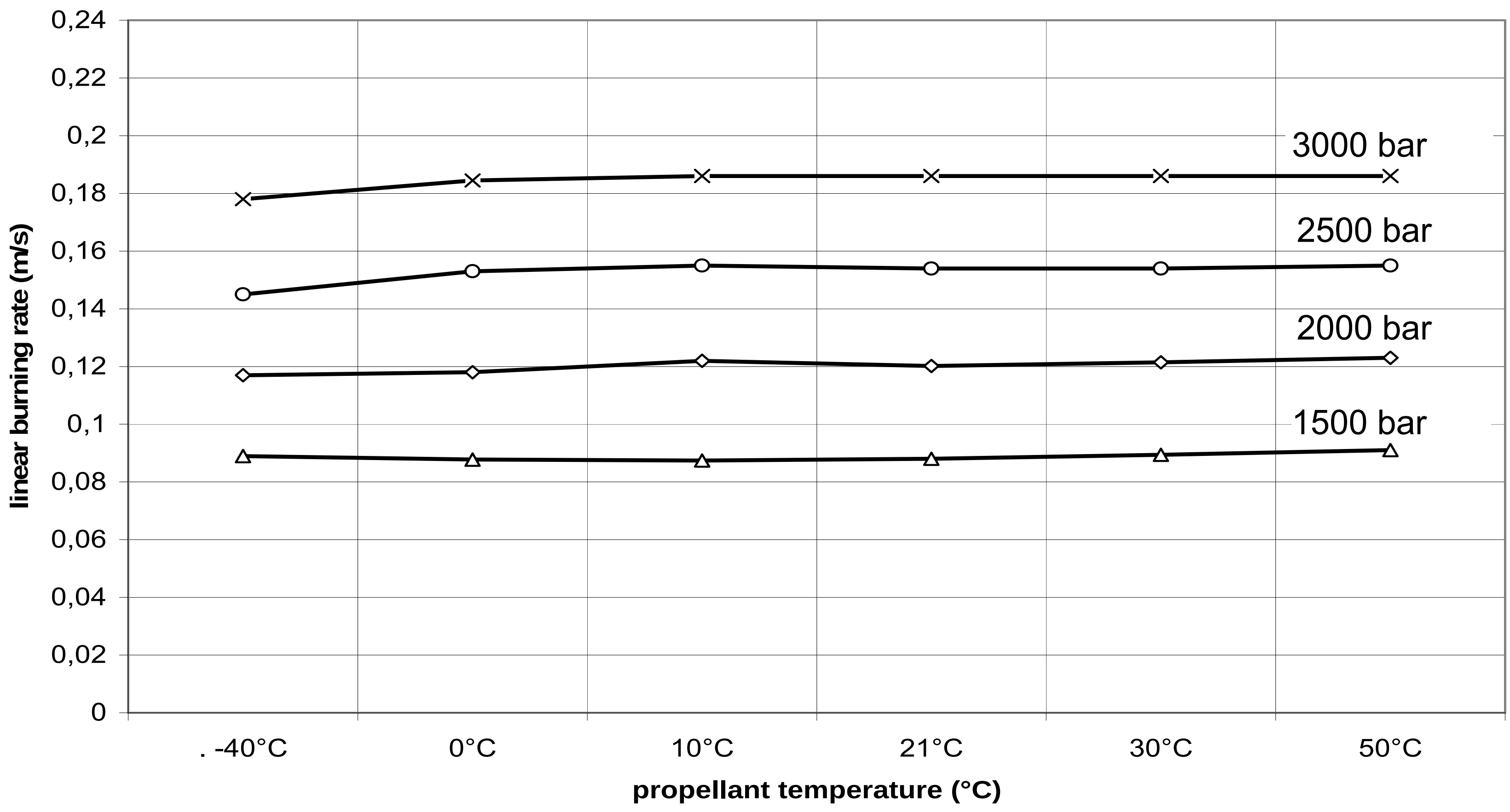
Linear burning rate of LTC Propellants at different pressures



Perfomance, Safety Test Results

Performance data

Formulation	Impetus (J/g)	T_f (K)	$\overline{M}w$ (g/mole)
1	1080	2540	19.4
2	1180	2910	20.8
3	1300	3990	21.6

Safety data

Loss of weight after 18 days	< 1.10 %
Loss of weight after 30 days	< 1.65 %
Sensitivity to friction	160 N
Sensitivity to impact	4 J
Self - Ignition temperature	> 220 °C
Fast cook - off test	burning
Shaped charge impact test	Class A

Sensitivity Data of different DNDA - Propellants

	RDX - Prop. ICT 1	i-RDX - Prop. ICT 20	RDX - Prop. mod. DNDA ICT 3
Reaktion Class Shaped Charge Test cal. 35 mm	A	A	B
	Propellant not burning, still in cartridge		
Friction Sensitivity [N]	288	240	240
Impact Sensitivity [Nm]	6,0	6,0	5,0
Ignition Temperature [°C]	> 220	> 216	> 219
1“ Detonation - Tube	no Detonation		
MG cal.50 / 12.7 mm	IM Reaktion Type 5 (MIL - STD 2105 B) WIWEB Results		

Shaped Charge Tests,

DNDA - Propellant ICT 1 (RDX), ICT 20 (i-RDX)

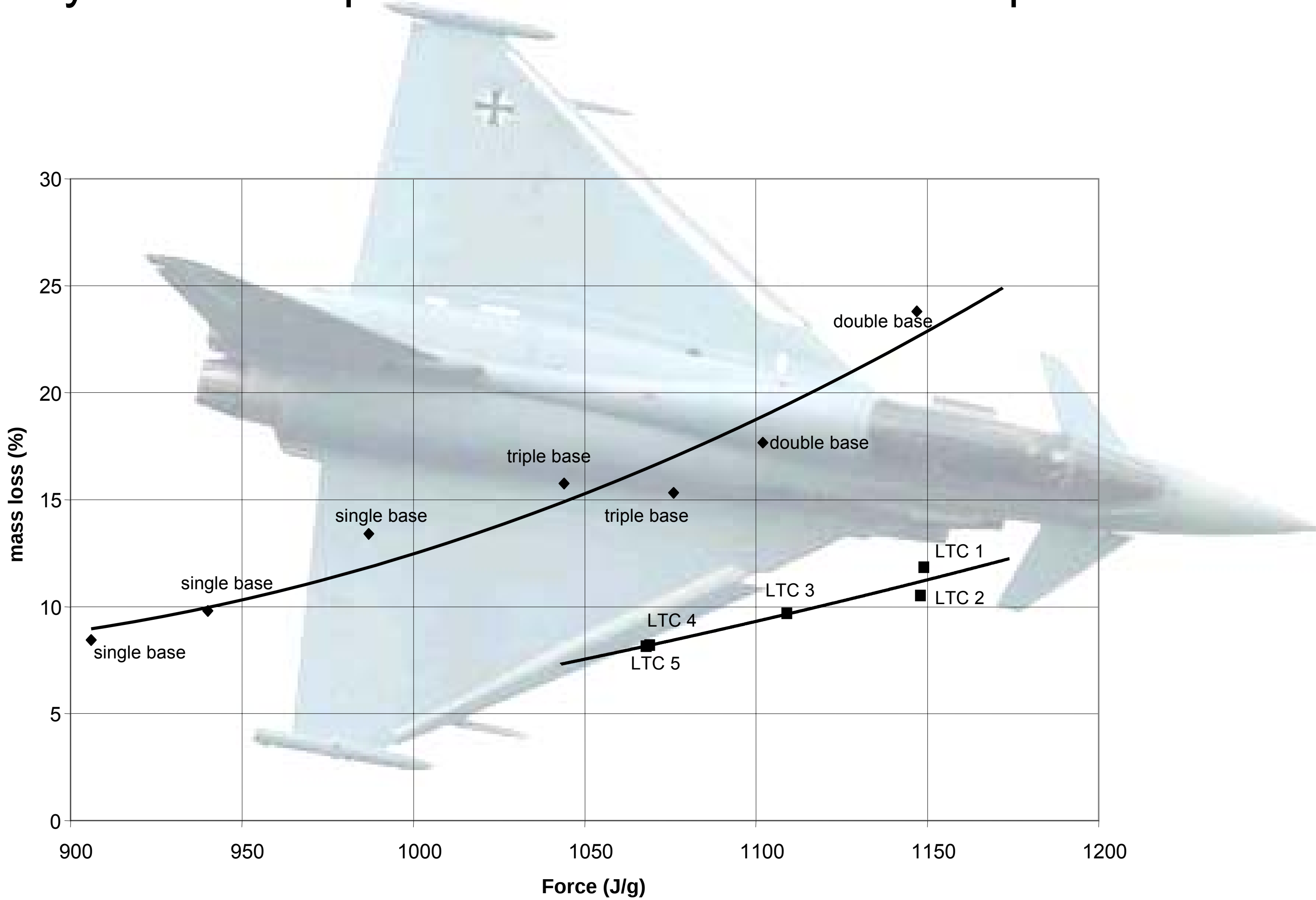
Class A

Class A

Shaped Charge Test,

DNDA - Propellant ICT 3, Class B Test Result

Erosivity of LTC Propellants and Conventional Propellants



Mue

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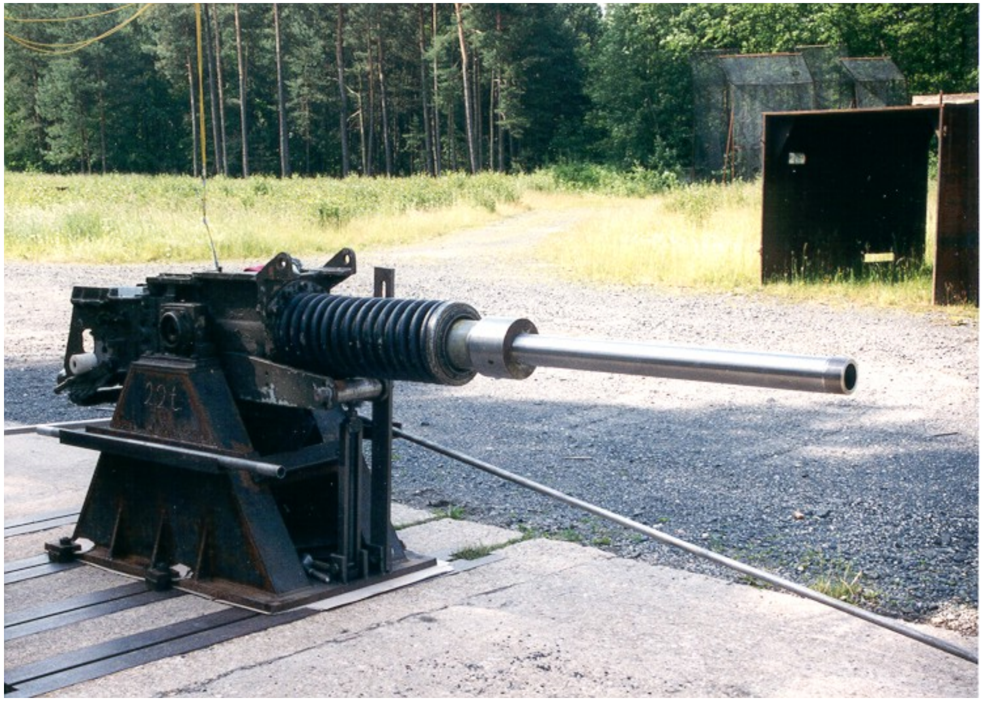
DIEHL BGT Defence

75 mm Scale model gun derived from 120 mm cal. tank gun (Diehl BGT)

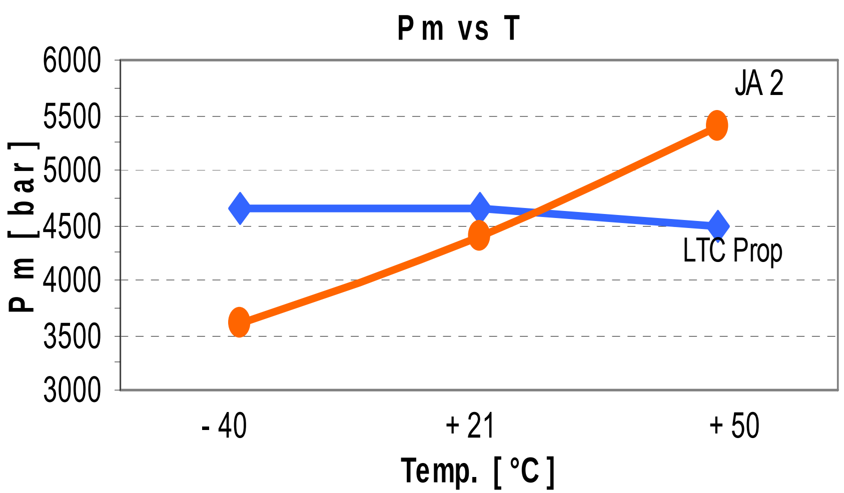
- based on interior ballistic similary laws
- less cost (combustible paper case, less propellant mass)



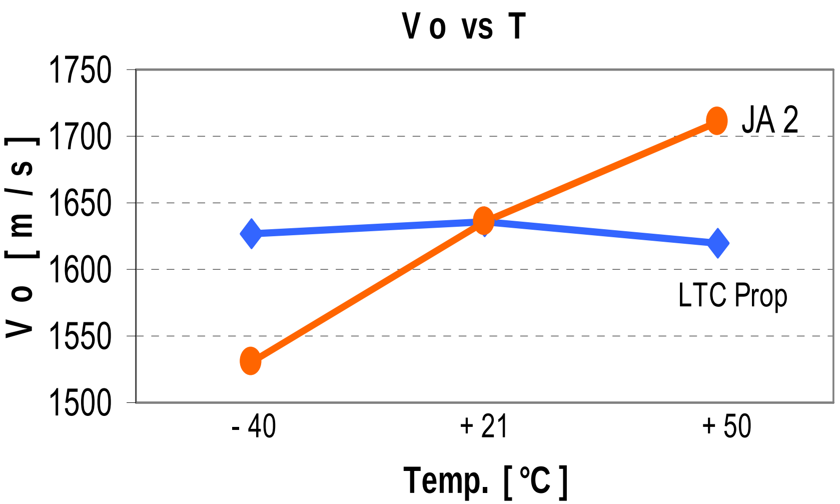
Test Firing in 75 mm cal. Model Gun (Diehl BGT)

Optimized propellant for firing at 21°C

gas pressure vs temp.



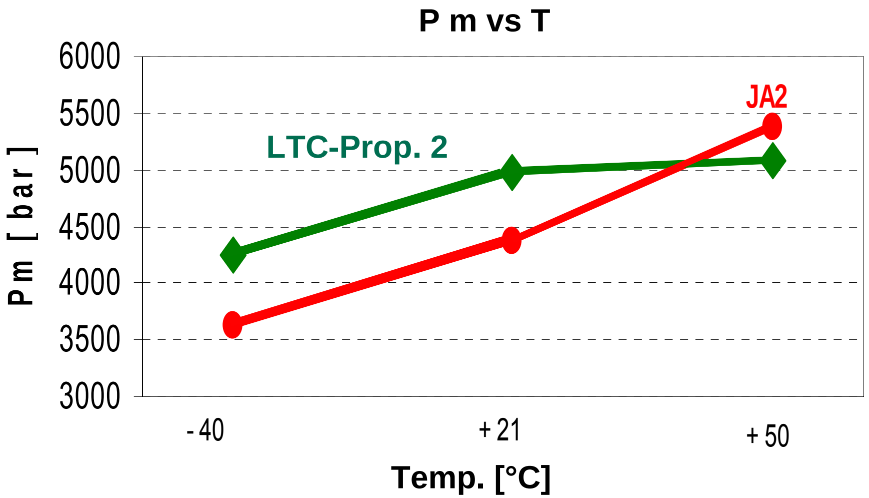
muzzle velocity vs temp.



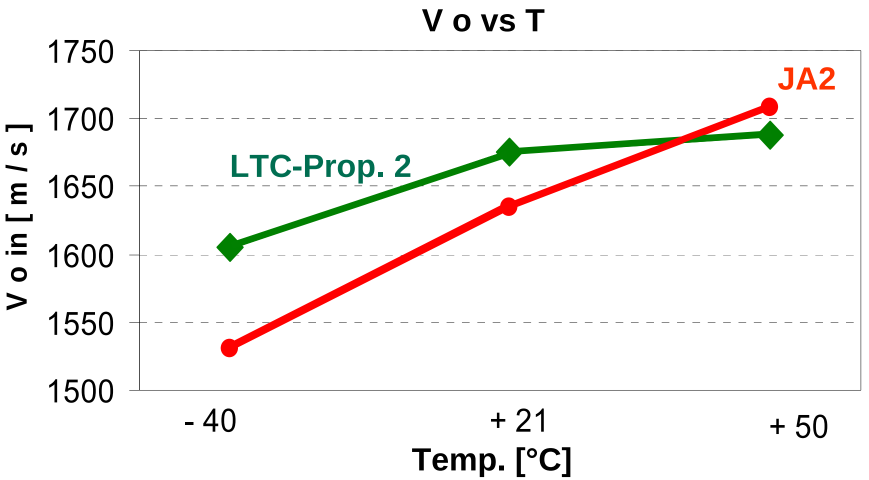
Test Firing in 75 mm cal. Model Gun (Diehl BGT)

Performance optimized propellant

gas pressure vs temp.

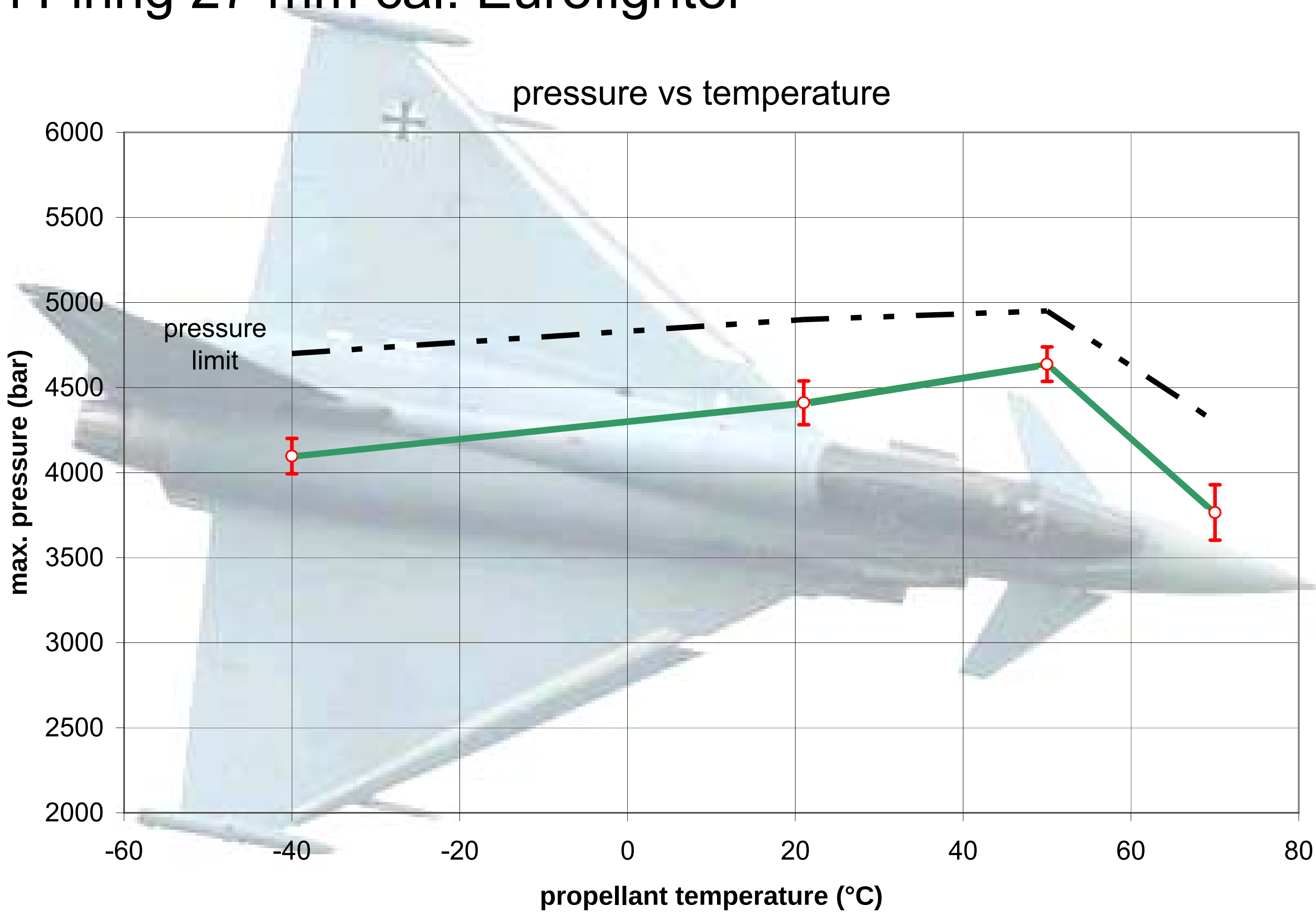


muzzle velocity vs temp.



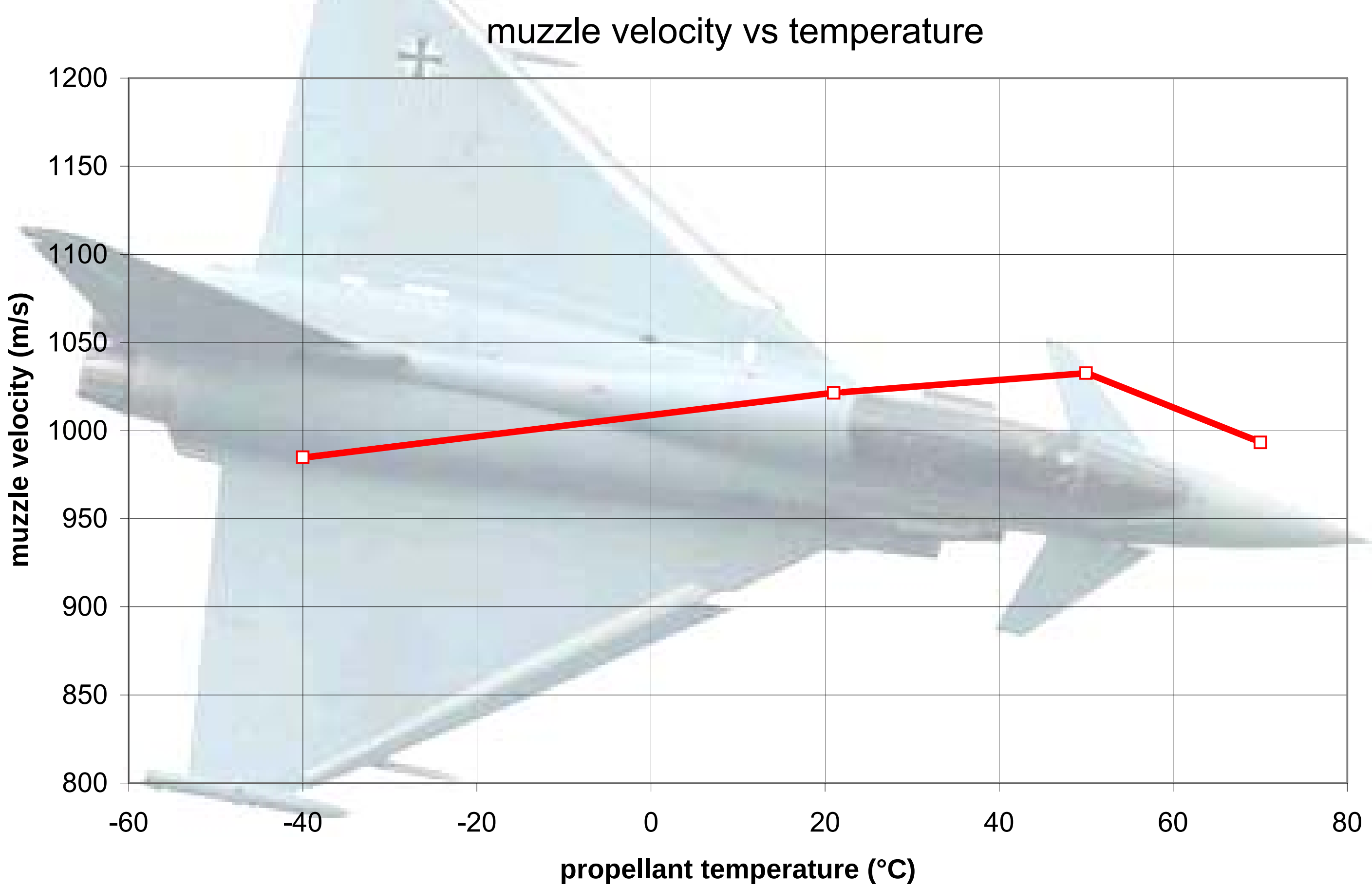
EF Propellant

Gun Firing 27 mm cal. Eurofighter



EF Propellant

Gun Firing 27 mm cal. Eurofighter



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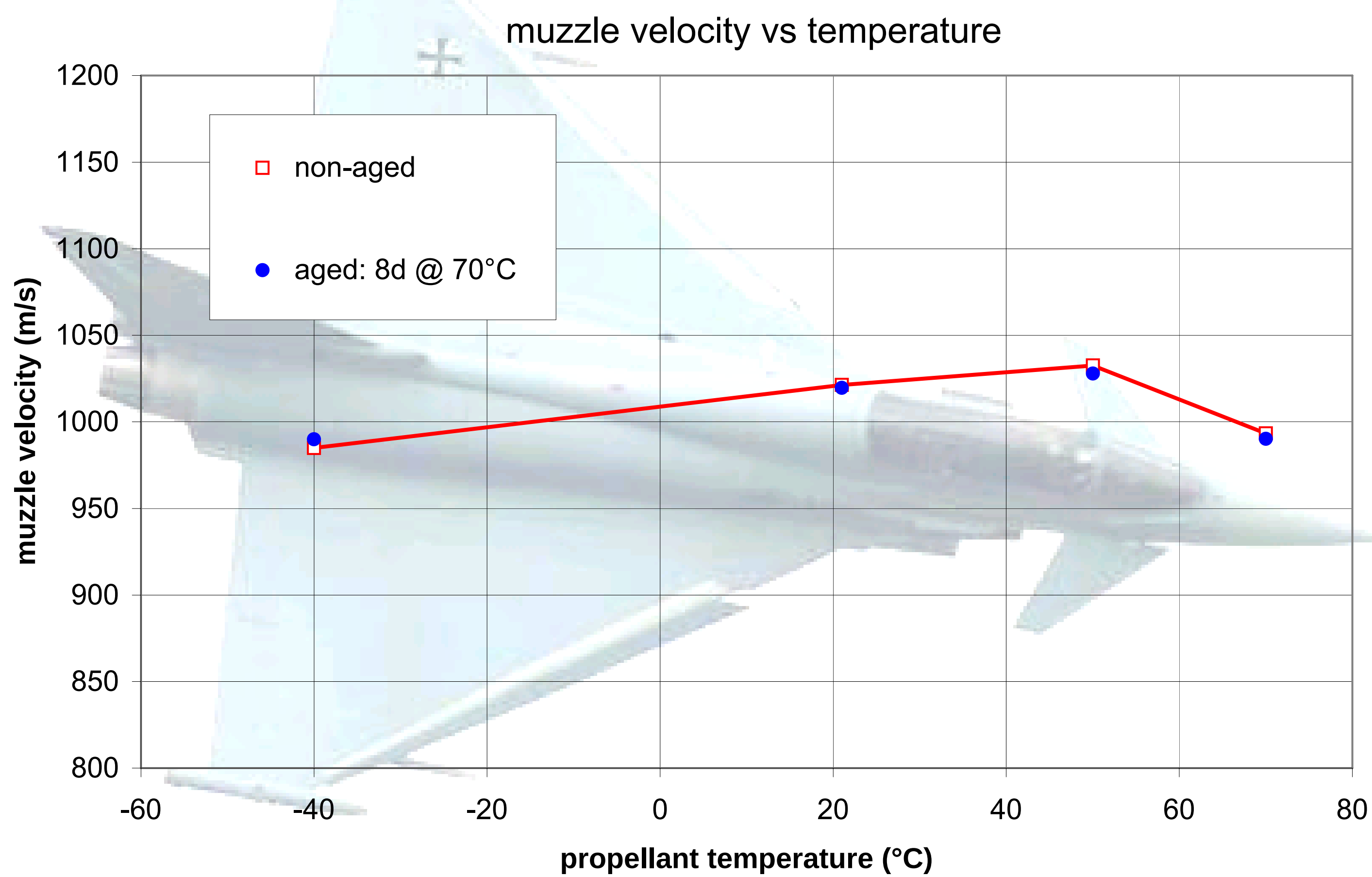
EF Propellant

Aged propellant compared with non aged propellant



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DIEHL BGT Defence

EF Propellant 27 mm cal. Eurofighter PELE Cartridge

Combustion Temperature	2900 K	Gun Erosion like Single Base Propellant
Force	1140 J/g	
Ignition Temperature	> 220 °C	

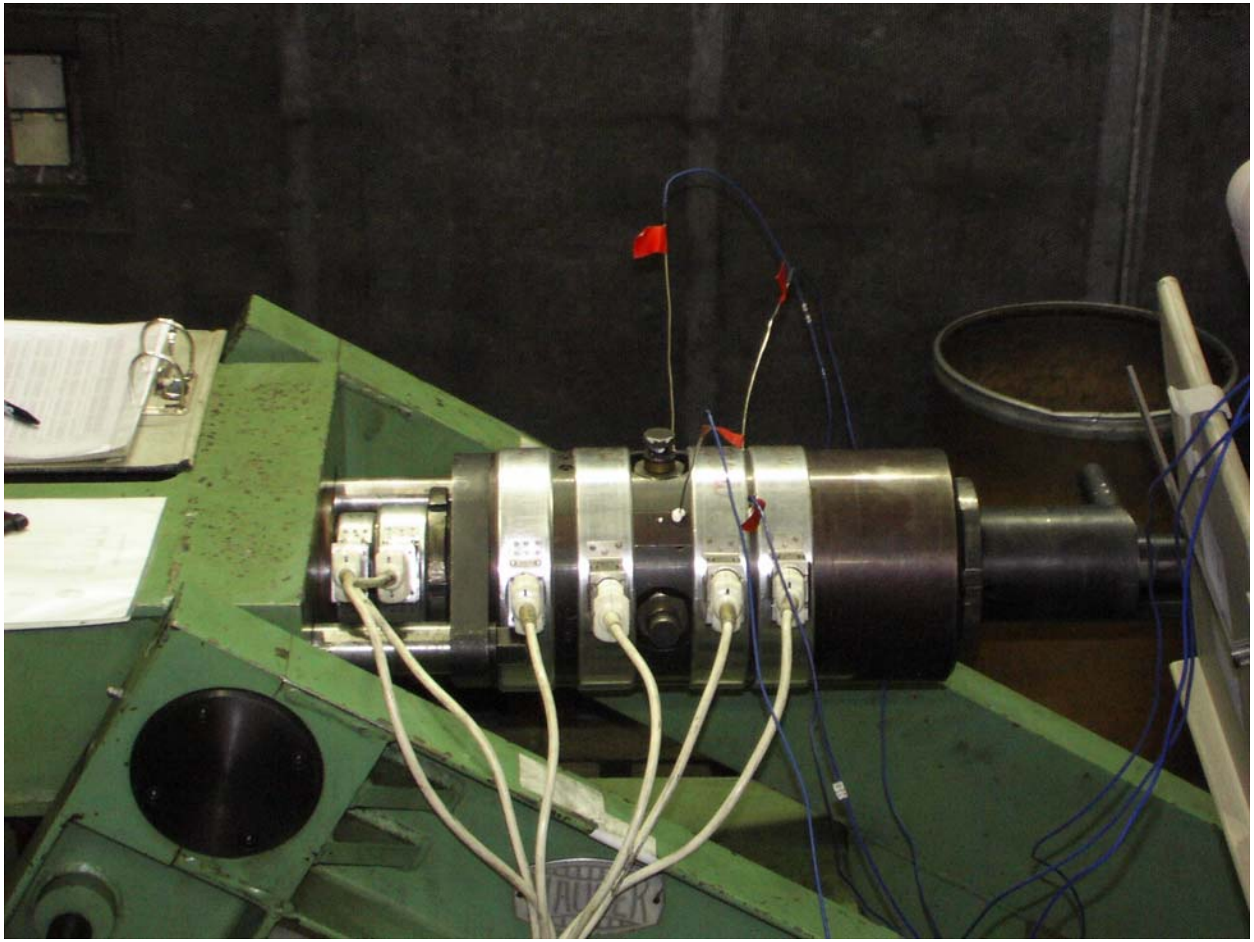
Cook - off Cartridge 27 mm cal.

27 mm Gun Tube Mauser, MATE (Mauser)

Q 5560 (Ref. Prop.)	125 °C	3,5 h	Ignition
EF Propellant	125 °C	8,5 h.	No Ignition

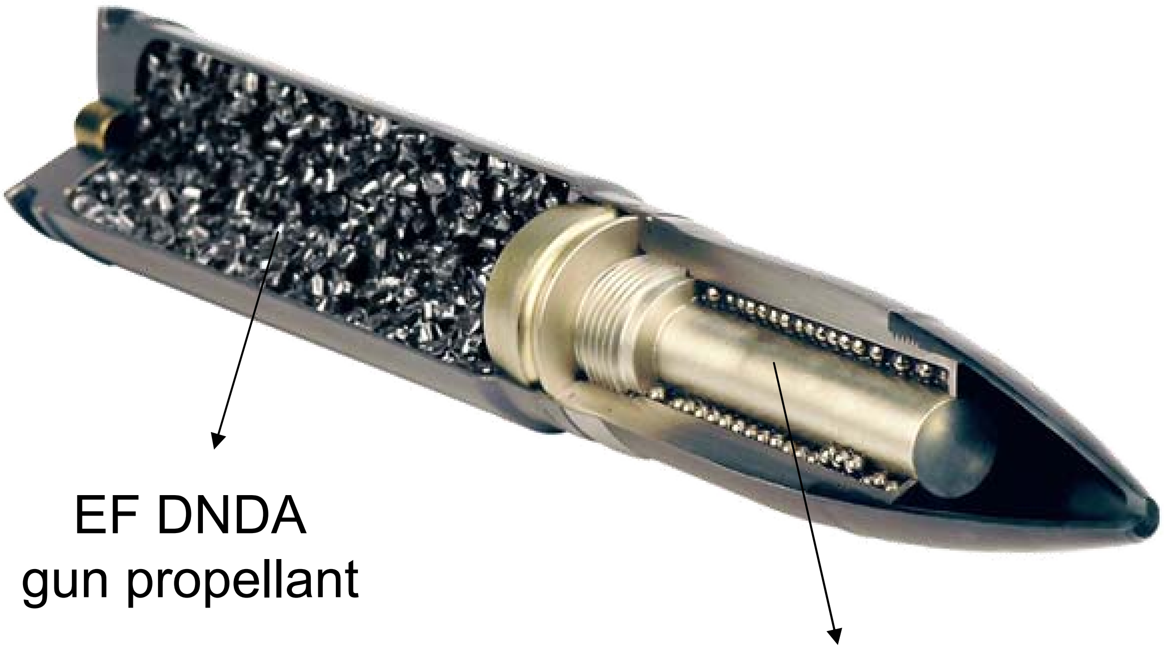
Cook - Off Test in Gun Tube 27 mm cal. (MATE)

Gun Test Tube

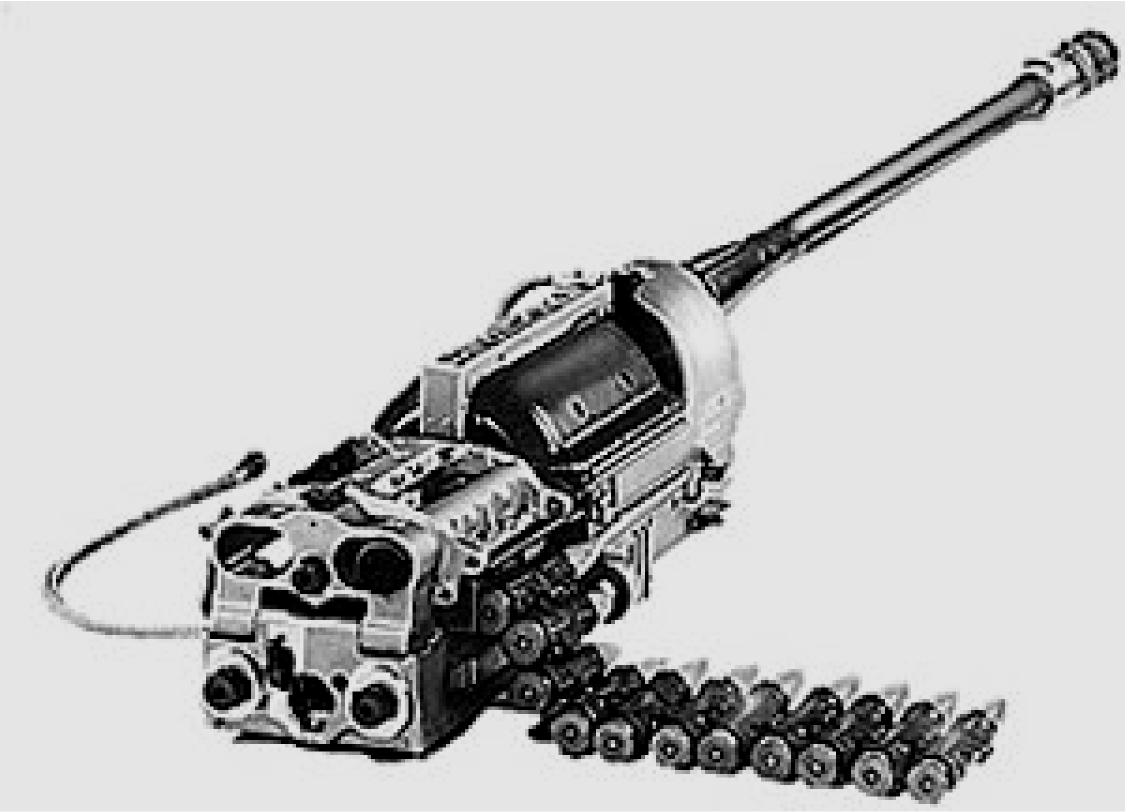


PELE Cartridge 27 mm cal.

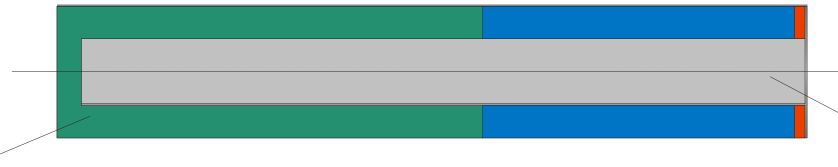
PELE = **P**enetrator with **E**nhanced **L**ateral **E**fficiency



Eurofighter BK 27
27 mm cal.



Diehl PELE Ammunition Concept



high density material for tube
I.e. tungsten, steel

low density material for inner core
I.e. plastic or aluminum

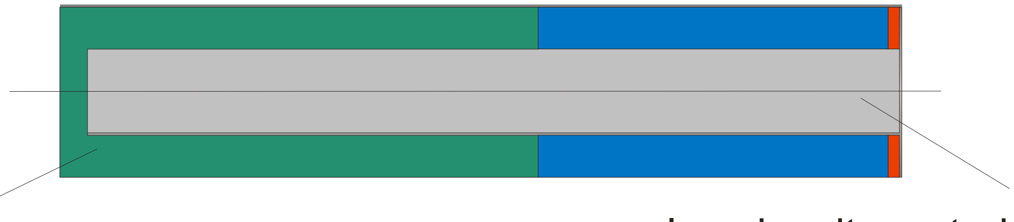
- PELE Projectiles
  → Highly effective against all targets

- New type of LTC propellant
  with low flame temperature (reduced erosion), high cook - off temperature
  - high shot precision within the temperature range
  - high internal ballistic safety

  No v_o - correction necessary

Mue

PELE Function



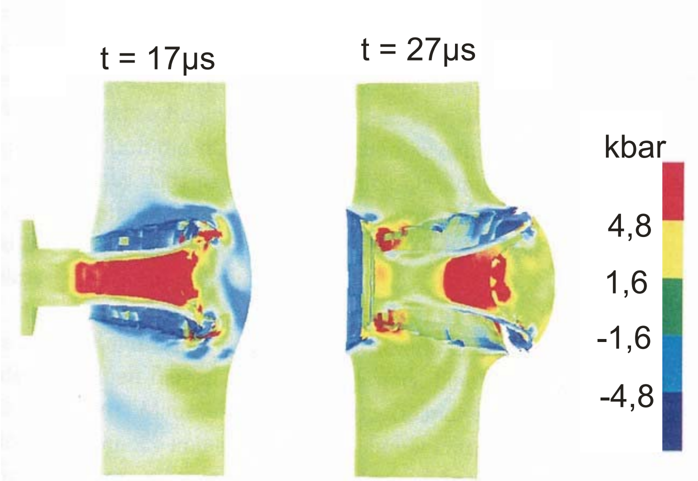
high density material for tube
I.e. tungsten, steel

low density material for inner core
I.e. plastic or aluminum

Part I: Erosion by penetration

Part II: Fragments by PELE effect
(Adjustable between 30% and 100%)

Part III: Penetration and/or PELE effect in next plates Adjustable between 0% and 70%)



Pressure distribution on penetrator

Results & Conclusion

- LTC Propellants based on DNDA 5,7 and RDX for a wide Caliber - Range
- Excellent Shaped Charge Testresults (Reaktion Class A)
- High Self - Ignition Temperature > 220 °C
- Insensitive, Reaction Type 5 (MIL - STD 2105 B)
  IM Characteristic
  MG 12.7 mm cal. firing on Steeltube with propellant
- Excellent Long - Term Stability
- Low Combustion Temperature at High Force and Low Gun Tube Erosion
- Less Sensitive in Hot Gun Tube (MATE)
- Propellant Charge for Eurofighter Gun, 27 mm cal. PELE Cartridge

Development of a

Projectile Muzzle Exit Sensor

Motivation

- Trigger cameras, flash x-ray, and radar
- Measure weapon system performance
- Get data for modeling and simulation
- Infrared (IR) sensors affected by blow-by gas from projectile, trigger prematurely

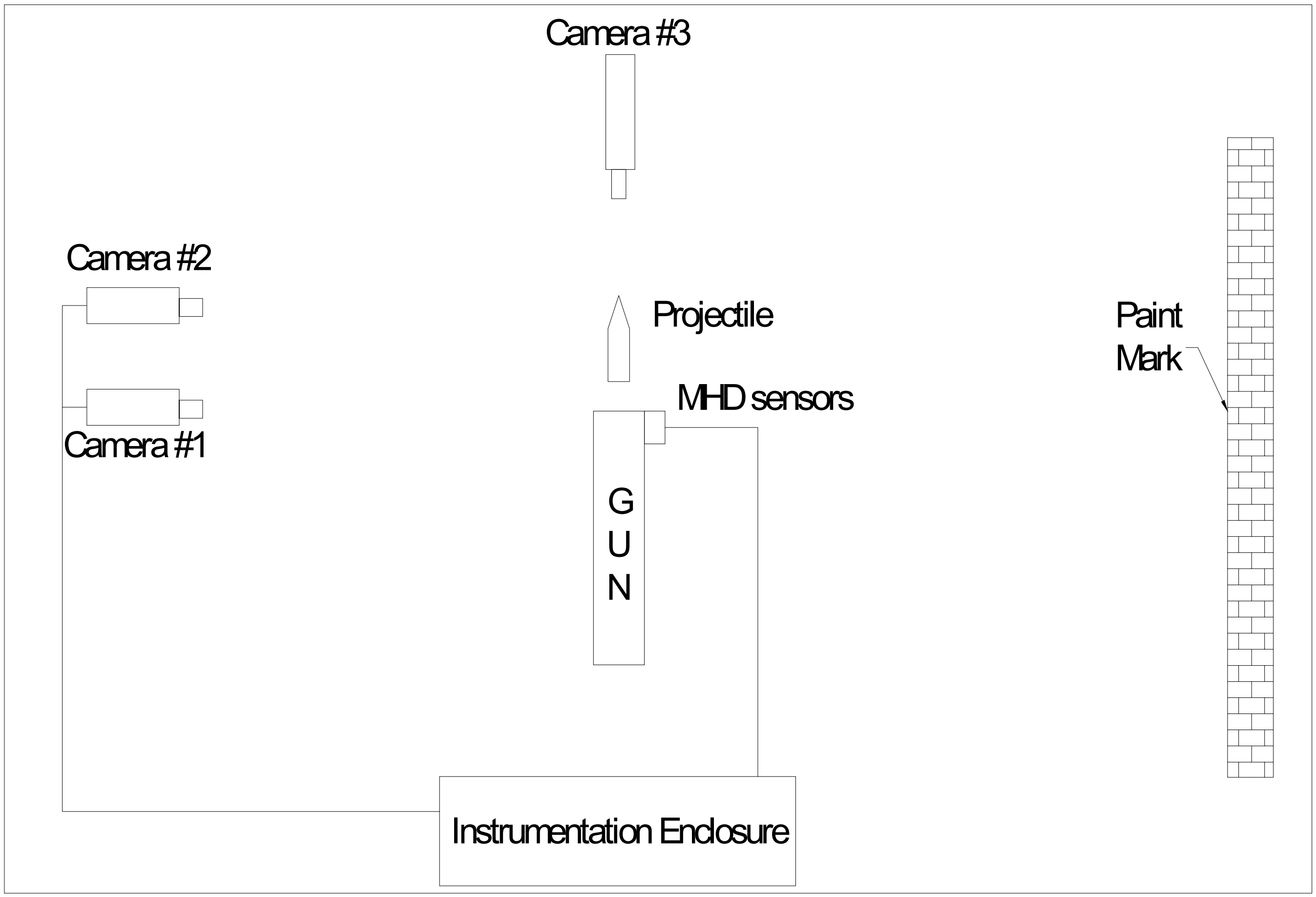
Sensor Design

- Magnetohydrodynamic Generator (MHD)
- Uses high-strength, permanent magnet
- Ionic, conductive gas layer from projectile exits gun at right angle to the magnetic field of the magnet
- Electrical charge is generated at right angle to magnetic field
- External excitation (ie battery) NOT required
- Attach to muzzle of gun
- US patent applied for by Contractor

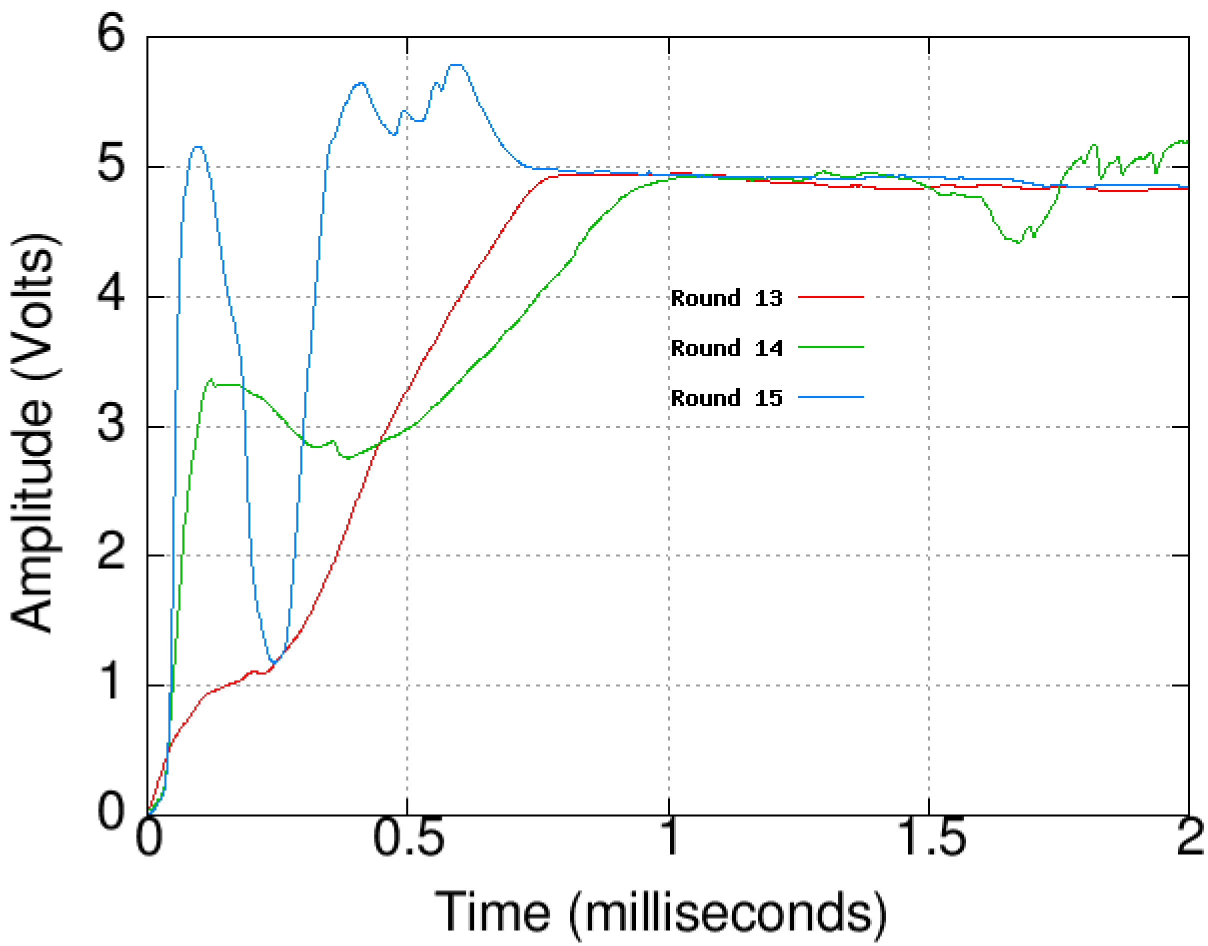
Prototype Test at ATC

- Sensors were attached to muzzle of M256, 120 mm diameter cannon, which had a severely eroded barrel
- Fifteen M865 rounds fired
- Sensor output triggered cameras which recorded high-speed images of projectile

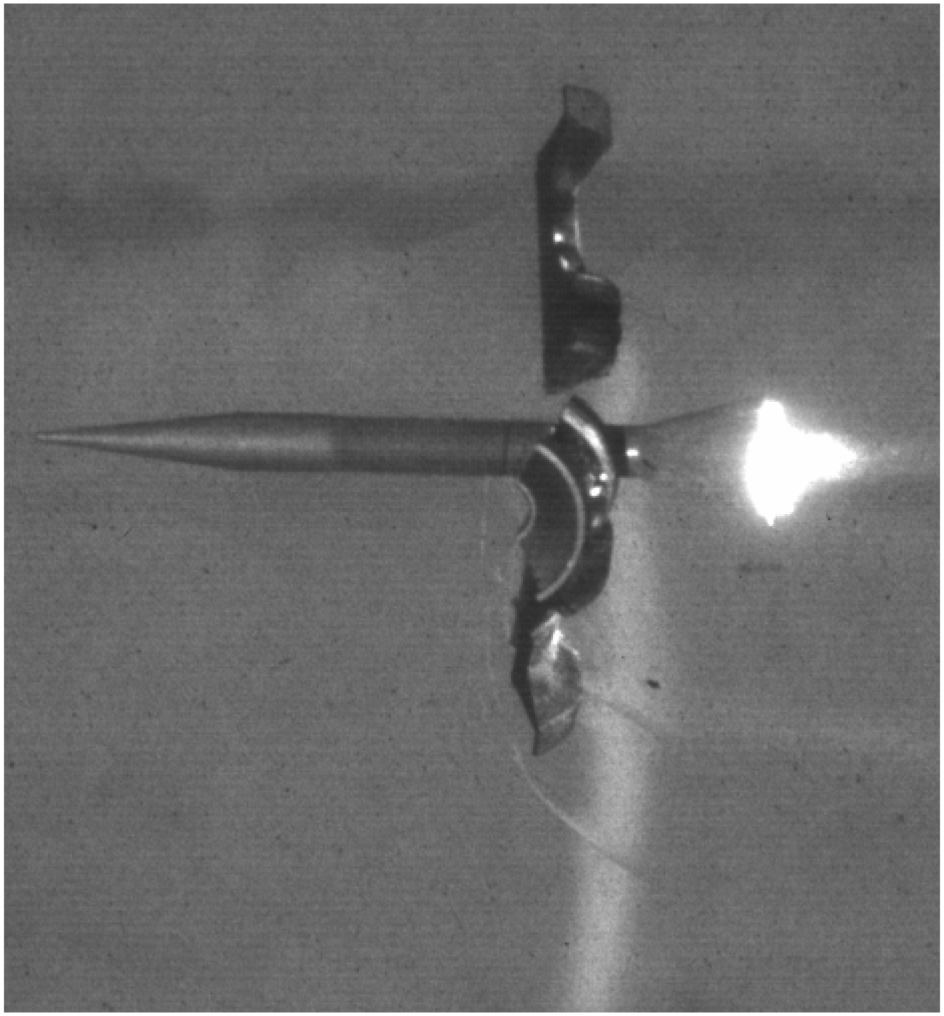
Range Test System Diagram



Amplitude vs Time for One MHD Sensor At The Same Location On The Muzzle For Three Consecutive Shots



Using The MHD Sensor to Trigger a High-Speed Camera Image



Muzzle Images During, and After Projectile Exiting the Cannon - Triggered by MHD Sensor

Projectile exits the gun.

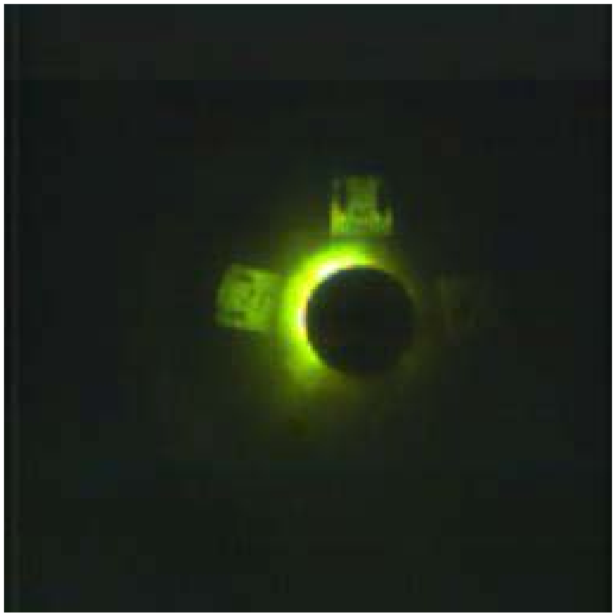
200 µsec later.

Note distance gun has recoiled.

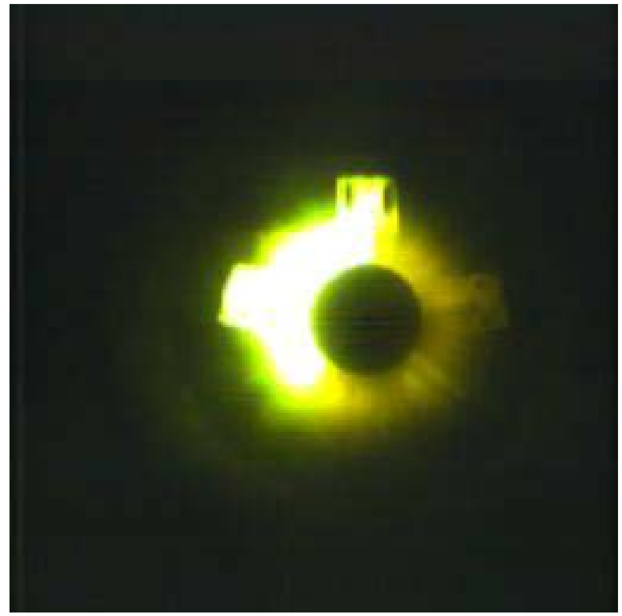
Two MHD Sensors Mounted on the Gun

Down Bore Image of Round Exiting Gun

The small size of fireball indicates fast response of MHD sensor.



The small amount of light indicates that the round is just beginning to exit the gun.



A short time later, more light at the left of the gun indicates asymmetrical gas leakage, which may adversely affect the flight.

Future Efforts

- Obtain faster, more consistent rise time
- Eliminate movement of muzzle mount
- Increase durability so it lasts for “many” shots
- Build sixteen prototype sensors and two muzzle mounts and test them at ATC
- Design and build “production” sensor

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Paladin Upgrade Through Integration of NDI technology

44th Annual Gun & Missile Systems Conference & Exhibition
Kansas City, MO

Peter D. Henry

BAE Systems Land & Armaments

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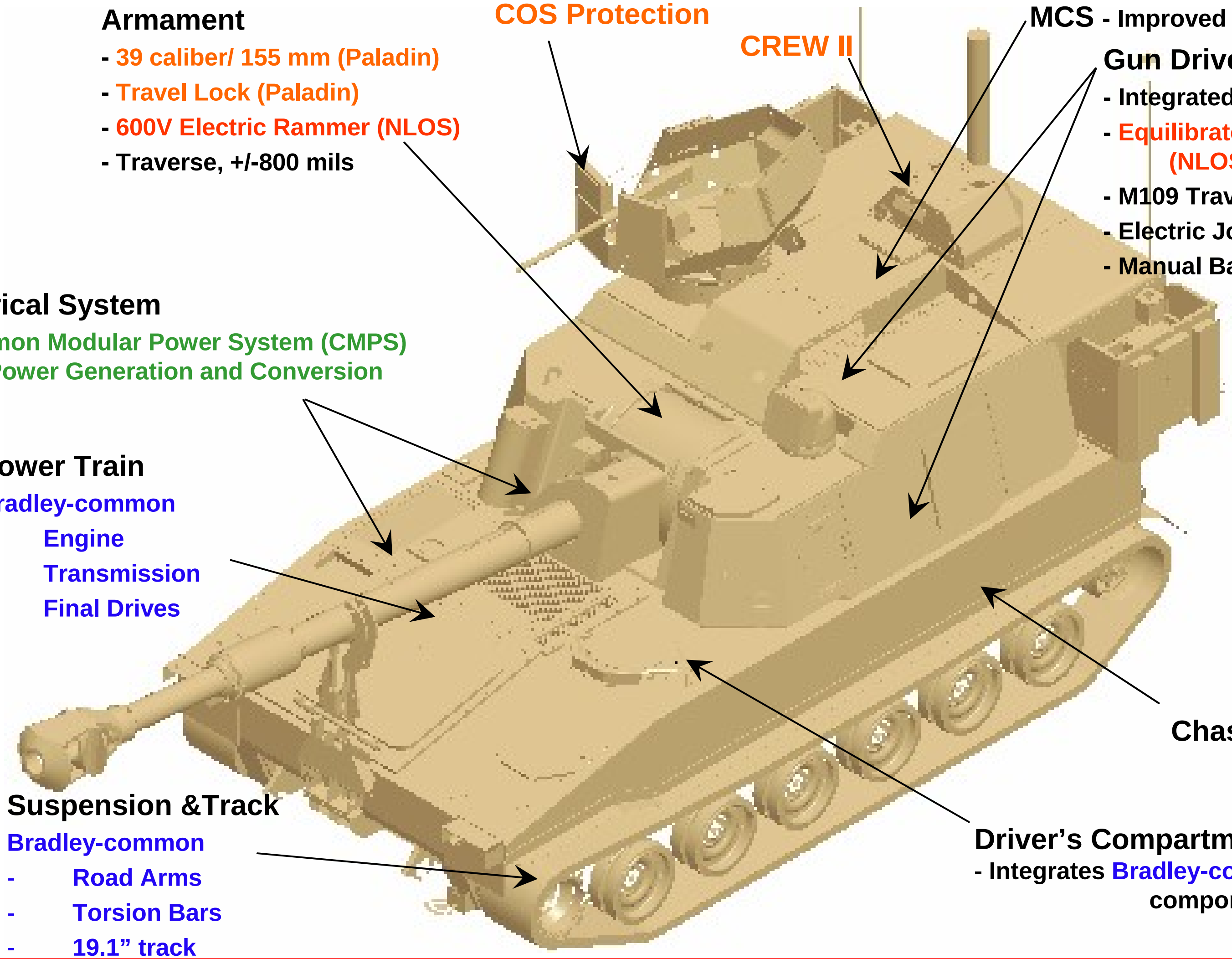
Background & Overview

- PIM program – Paladin/FAASV Integrated Management
  - An integrated effort to ensure long-term viability & sustainability of the primary indirect fire weapons platform in the Heavy Brigades
  - Maximizes commonality with supported systems; minimizes development (primarily an integration activity)
  - Provides digital "backbone" to support Army wide VHM initiatives in longer-term
- Program includes replacement of hydraulic gun drives and rammer with high-voltage electric components
  - Hydraulics are a top-10 sustainment cost driver on M109A6
  - M109A6 slip ring is also a maintenance driver

PIM-SPH Objective Configuration Overview



Armament
- 39 caliber/ 155 mm (Paladin)
- Travel Lock (Paladin)
- 600V Electric Rammer (NLOS)
- Traverse, +/-800 mils

COS Protection

CREW II

MCS - Improved

Gun Drives
- Integrated with PDFCS
- Equilibrated Elev Mech w/600V motor (NLOS)
- M109 Traverse Mech w/600V motor
- Electric Joysticks
- Manual Backups to drive Gun

Electrical System
- Common Modular Power System (CMPS) Power Generation and Conversion

Power Train

Bradley-common
- Engine
- Transmission
- Final Drives

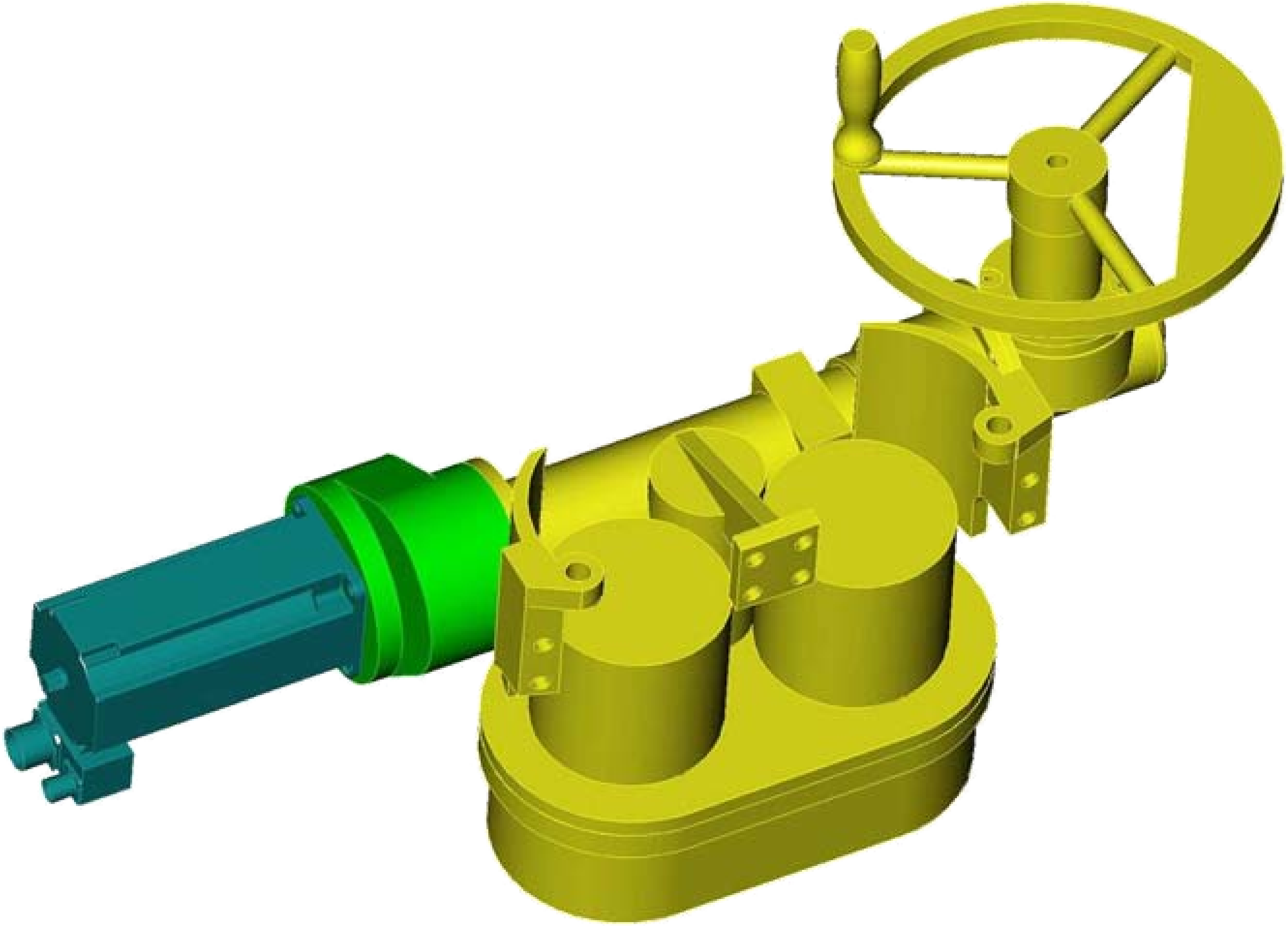
Chassis (new structure)

Suspension &Track

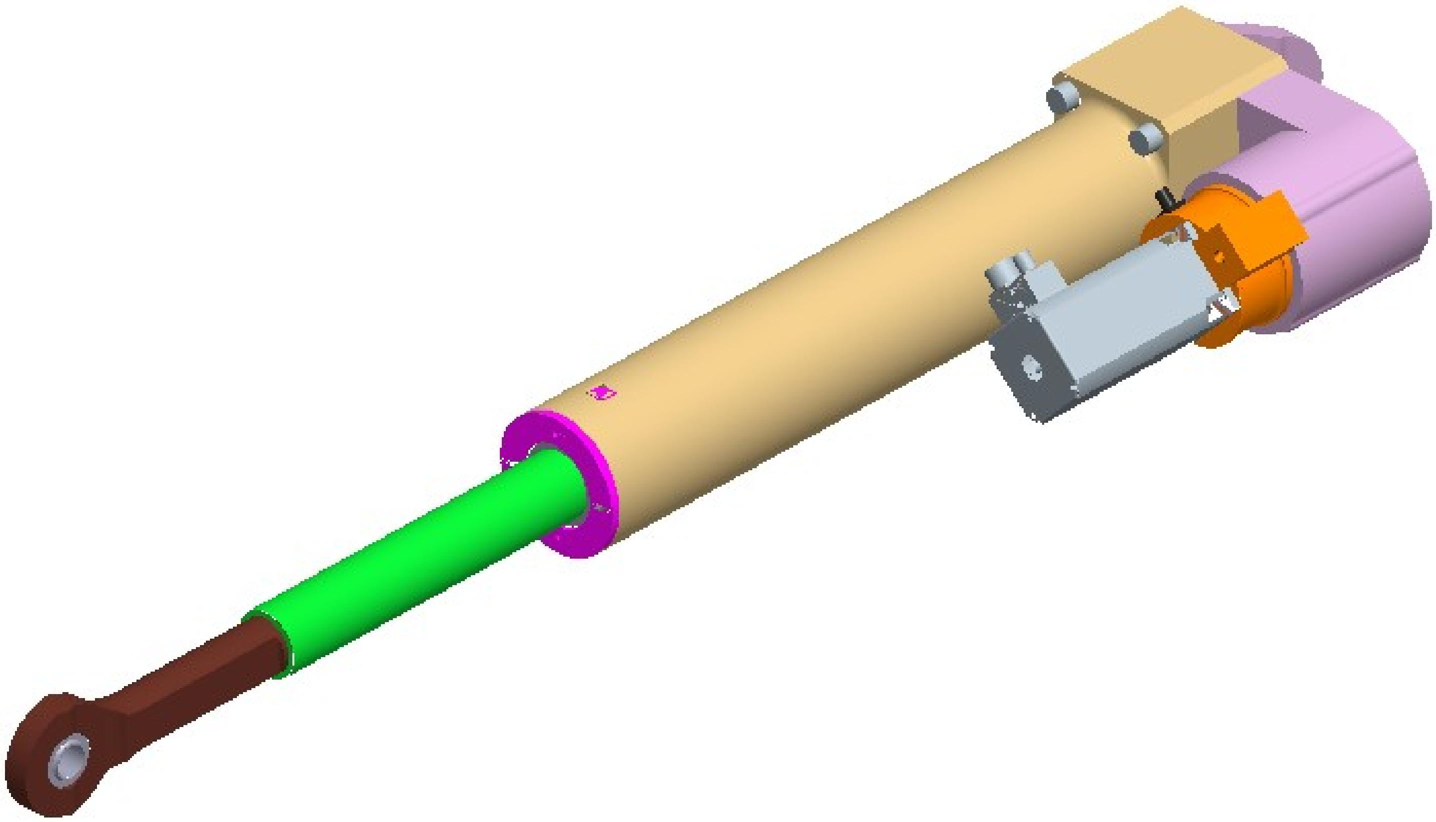
Bradley-common
- Road Arms
- Torsion Bars
- 19.1” track

Driver’s Compartment
- Integrates Bradley-common and Paladin components

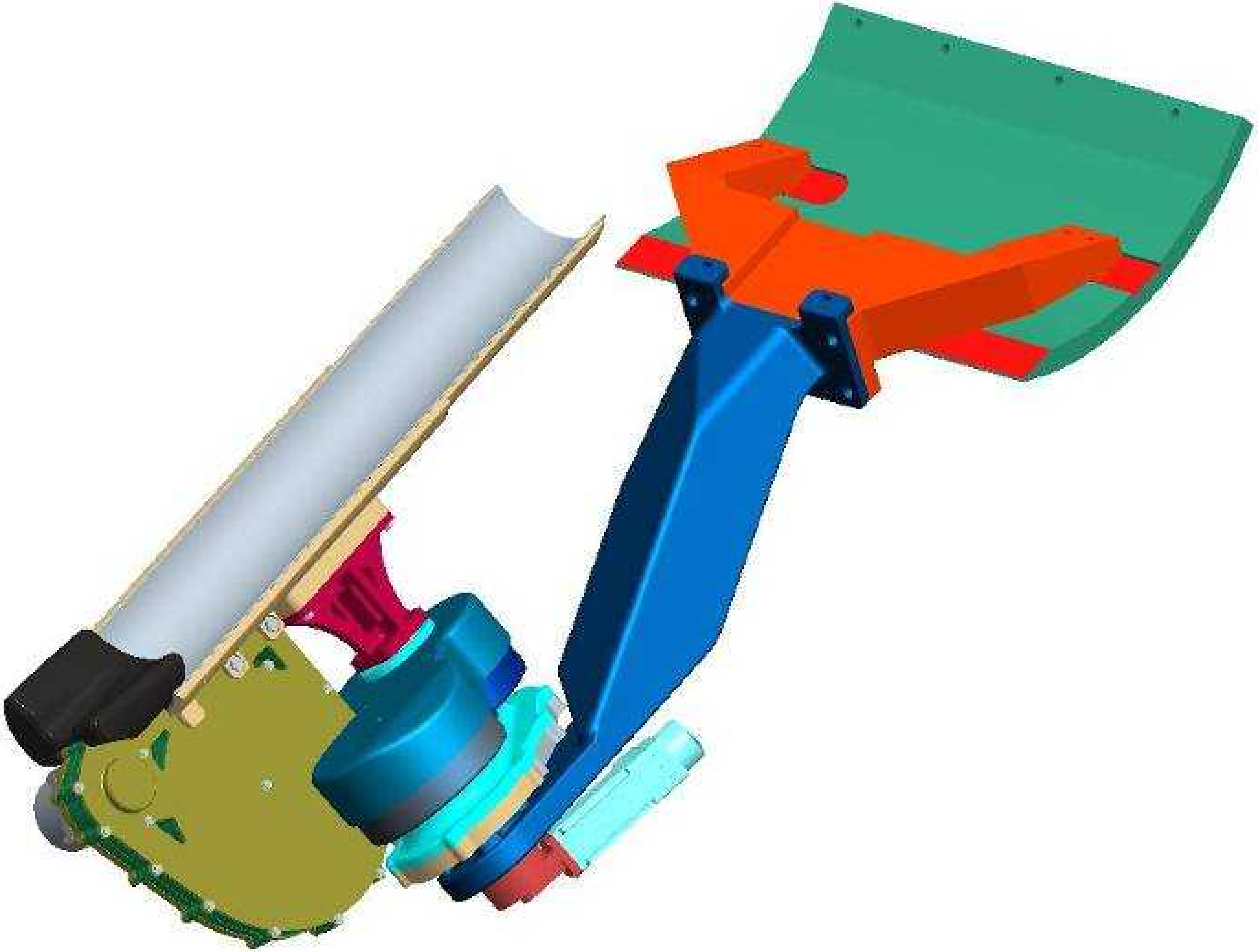
Traverse Mechanism with Electric Drive



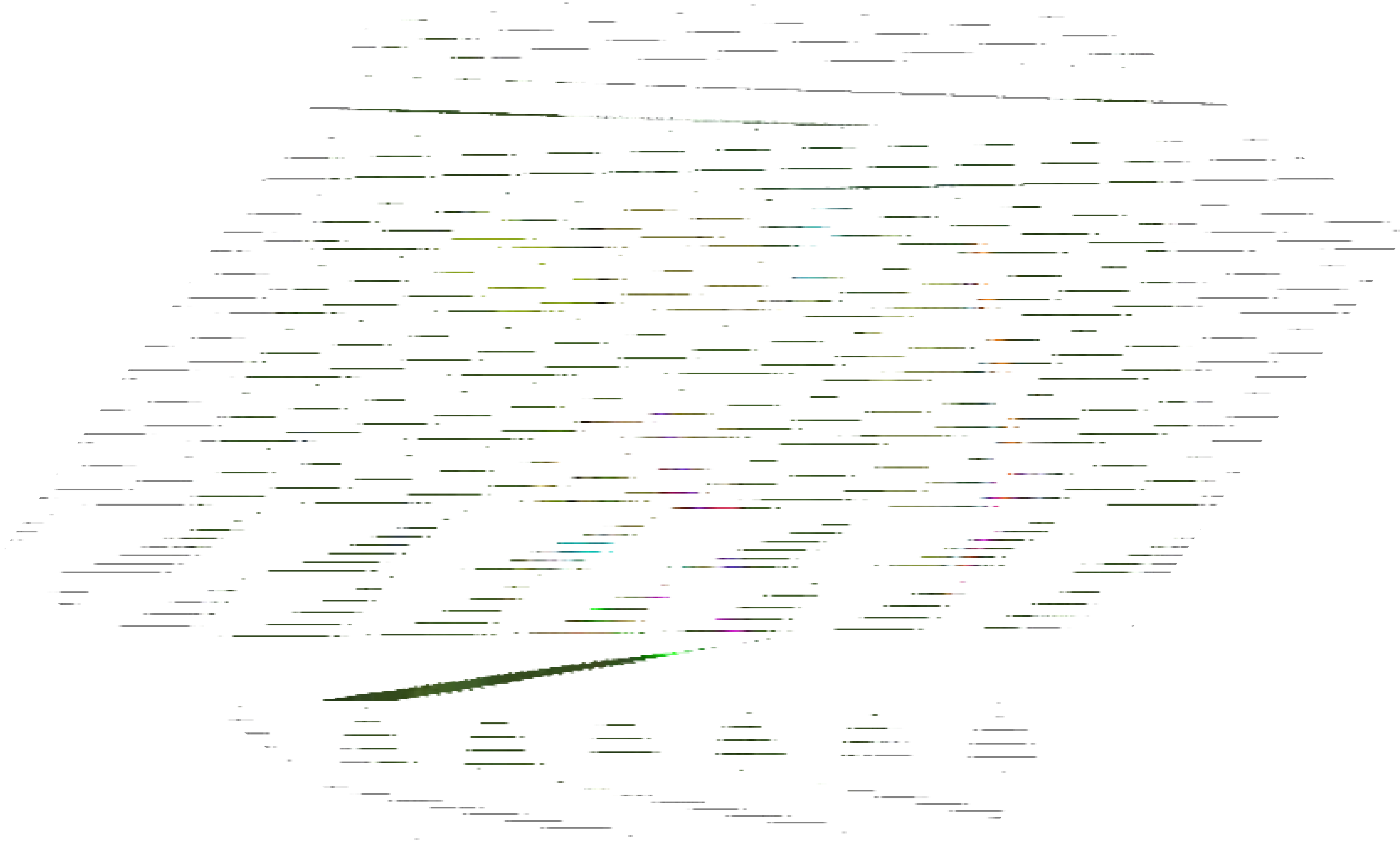
Electric Elevation Drive



Electric Projectile Rammer



Control components housed in former hydraulics compartment



Challenges

- TRL
  - What TRL is adequate for technology reuse?
  - Don’t neglect the effect of integration on TRL!
- Challenges inherent in a sustainment project
  - Baseline performance characteristics may be incompletely specified in existing requirements documentation
  - User may be accustomed to or reliant on features that are not in the defined requirements baseline
  - Design baseline developed using lower-maturity processes and standards
- Despite focus on sustainability rather than new functions or improved performance, requirements creep remains a challenge

BAE SYSTEMS

Summary

- PIM leverages components, systems and proven technologies available today to ensure that the Paladin/FAASV fleet remains sustainable beyond 2050
- Electric drive contributes to improved system reliability and sustainability
- HBCT commonality reduces development, acquisition and sustainment costs

GENERAL DYNAMICS
Ordnance and Tactical Systems




GD-OTS Propellant Program

HIGH DENSITY, MULTI-GRANULATION, PROPELLING CHARGE DESIGN

April 7, 2009

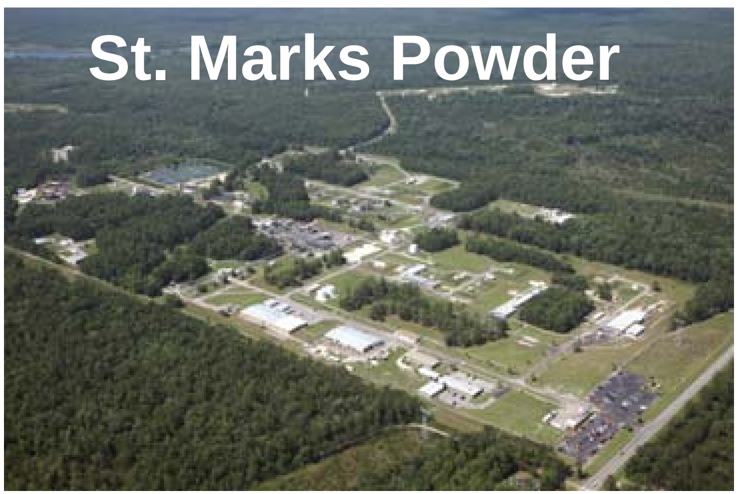
Daniel Lepage - Valleyfield

Bob Pulver – St. Marks Powder

GD-OTS Propellant Capabilities

GD-OTS
St. Marks Powder
Producing Propellant
Since 1970
1974 Acres,
# of Buildings - 137
# of Employees - 350

GD-OTS Canada
Valleyfield
Producing Propellant
Since 1941
1112 Acres,
# of Buildings – 180
# of Employees - 420



High Performance Propellant Technology

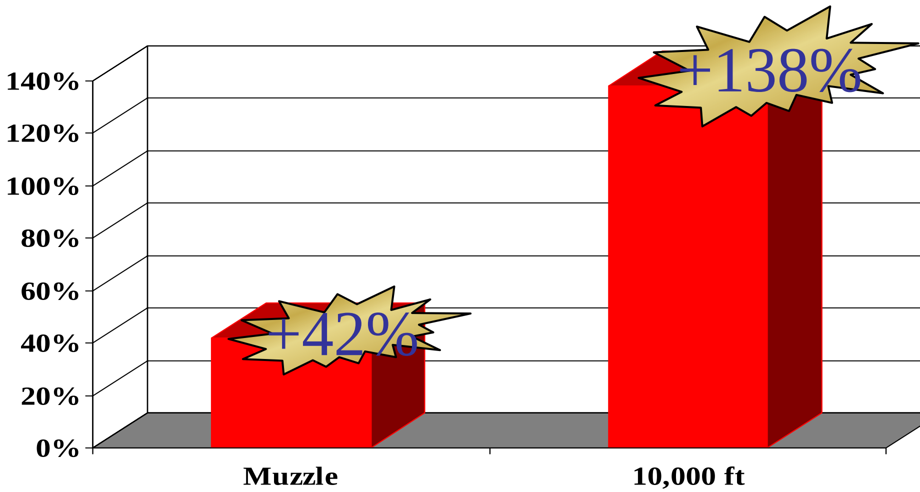
High Loading Density
+ Ballistic Efficiency
= High Performance

The ability to achieve higher charge weights combined with the appropriate burn progressivity (ballistic efficiency) will yield higher performance capabilities

High Loading Density
Performance Improvements
Demonstrated in 20mm Mk-244

- Increased Kinetic energy with heavier projectiles
- Reduced Time of Flight
- Flat Temperature Sensitivity
- Improved Ballistic Stability
- ***Low Flame Temperature for Longer Barrel Life***

High Loading Density Charge – Proven Technology



Maximum Kinetic Energy

Example:

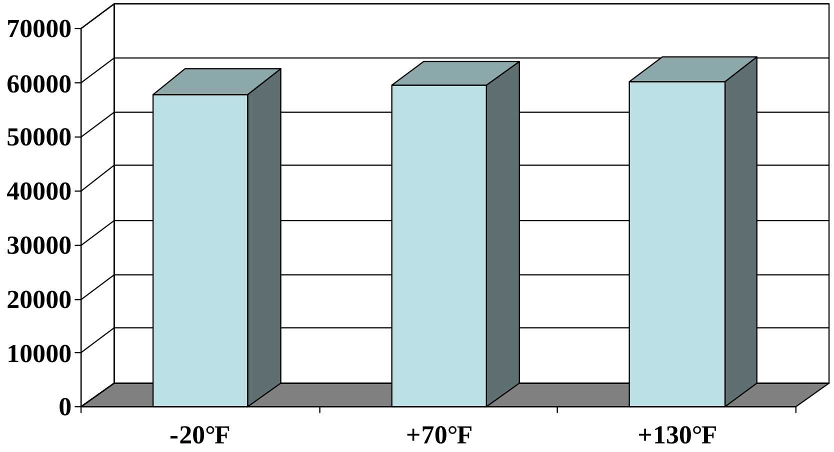
<u>20mm Phalanx Ammunition</u>

Mk-149 Loose Loaded Charge

Mk-244 Compacted Loaded Charge

(+ 25% in Propellant Charge Weight)

Excellent Temperature Sensitivity



High Performance Propellant Technology

Compacted Propellant Charge → Excellent for minimal projectile case intrusion

Mixed Propellant Charge → Excellent for applications with significant projectile case intrusion such as KE rounds

Mixed Charge Propellant Concept

High Density, High Performance Charge provides up to ***25%**** higher charge weights than typical Loose Loaded charge

** In laboratory studies*

Mixed Propellant Charge - Objective

- Objective: Demonstrate this concept in ammunition to achieve improved ballistic performance
  - Chose 30mm GAU-8/A PGU-15 /B TP ammunition as a Baseline
  - Valleyfield started with a 7-Perf, surface deterred, extruded propellant
  - Blended in a small diameter, surface deterred, BALL POWDER® propellant
  - Loaded with vibration

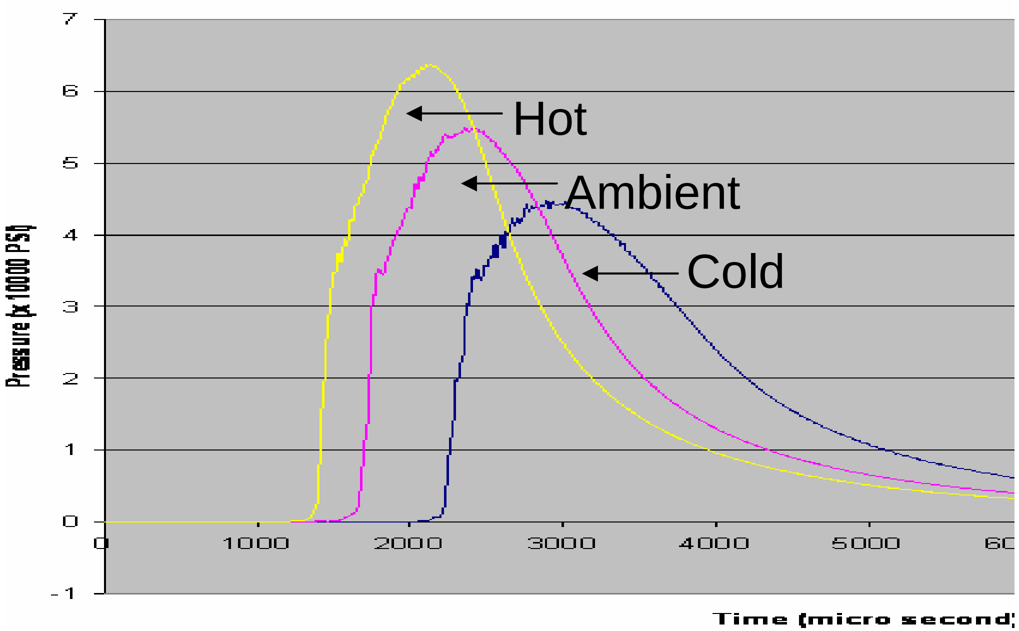
Achieved 17% charge weight increase with excellent ballistic efficiency

30mm Ballistic Results

Baseline @ 145 grams = 3,340 fps 50,000 psi

Mixed Charge @ 170 grams = 3,623 fps 56,000 psi

Represents a 18% increase in Kinetic Energy with low flame temperature propellant charge



Typical temperature sensitivity with very good standard deviations

Bottom Line: Excellent combustion dynamics with the mixed charge

30mm Ballistic Results - Projected

Baseline @ 145 grams = 3,340 fps

1st Iteration Mixed Charge @ 170 grams = 3,623 fps

Planned Iteration Mixed Charge @ 188 grams = 3,730 fps

Represents a 25% increase in Kinetic Energy

Mixed Propellant Charge – Future Work

Future Work

- Maximize Charge Weights
  - *Geometry and Loading Studies*
- Maximize ballistic efficiency with deterrent technology
- Optimize Standard Deviations and Temperature Sensitivity
  - *Propellant chemistry (Compatibility)*
  - *Ignition system*
- Ensure excellent long-term, hot temperature ballistic storage
- Ensure excellent IM properties

Mixed Charge Propellant Concept - Summary

Large Multi-Perf, Deterred, Extruded Propellant

\+ Small Deterred BALL POWDER® Propellant

= High Density, High Performance Mixed Charge

GD-OTS Valleyfield and St. Marks Powder have the technical know-how to develop high performance, high propellant density charges for maximum performance

Development Team

St. Marks Powder

- Bill O'Meara, Manager, Product Development
- Tim Ulrey, R&D Development Engineer

GD OTS-Canada Valleyfield

- Mathieu Racette, R&D Project Officer, Small and Medium Calibre Ammunition
- Frederick Paquet, R&D Project Officer, Large Calibre Internal Ballistics
- Pierre-Yves Paradis, R&D Coordinator

ECL® Propellant Demonstration for Extended Range in 120mm Mortar combined with Ballistic and Chemical Stability Equals Win for the Warfighter

Kelly Moran, Jim Wedwick (ATK)
Howard Shimm (ARDEC)
Ulrich Schaedeli, Dominik Antenen, Kurt Ryf (Nitrochemie)

NDIA Conference
44th Annual Gun & Missile System Conference
Kansas City, 7th April 2009

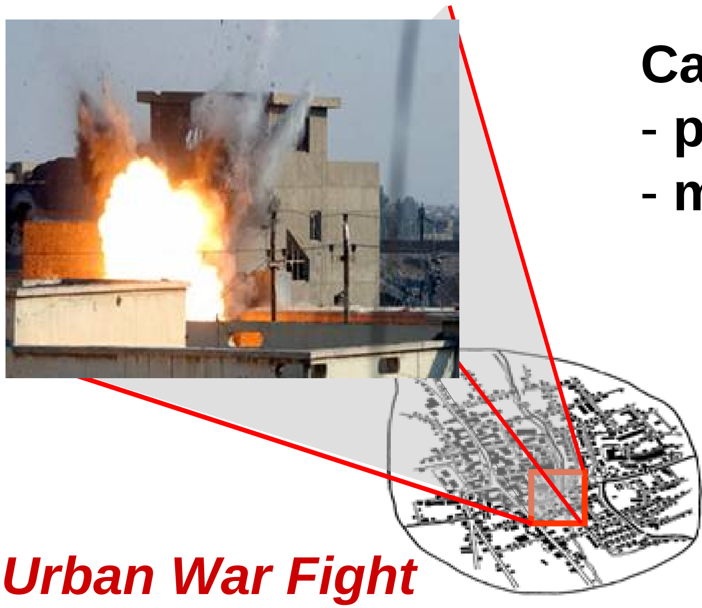
General Requirements for Future Close Fight

Main Goals

- New "hit target" precise rounds
  Suppression → *Destruction*
- Compensation for heavier or high drag precision optimized projectiles
  use current firing tables
- Potential for extension of battle space ranges
- Reducing number of rounds fired and time to fire those rounds
- Reducing risks of collateral damage to civilians and valued infrastructure

Propulsion System = decisive element in a chain of different system approaches for fulfillment of future requirements

General Requirements for Future Close Fight



Capability: urban clutter, rubbled terrain
- precision engagements (collateral damage)
- mobility and survivability

Propulsion specific requirements:
- **shelf life (extreme loads)**
- **safety, reliability, consistency**
- **energy density for range improvements**

Urban War Fight

Capability: complex terrain and vegetation
- extended range (battle space)
- precision optimized

Range Requirement

Prospective Path for Future Close Fight

	Today	2010 - 2012	20xx
Munition	**Current HE**	**Precision Optimized**	**Precision Optimized**
Lethality	**Area fire***	**Destruction (protected troops in bunkers, urban structures or vehicles)**	**Destruction**
Range	**7.2 km**	**7.2 - 10 km**	**10 – 12 km****

* Suppression of enemy troops

** Depending on system approach

New advanced propulsion technology is available for offering significant benefits for such future system solutions!

Advantages of ECL® Propellants in Mortar Applications

- Main Benefits of new ECL® propellants compared to current nitroglycerine-containing propellant solutions:
- **Improved performance potential** due to
  - High energy density and thermal conversion
  - Tunable force level, favorable thermodynamic features
- Improved dispersion (v), consistency and repeatability (lot to lot)
- ⇨ **improved accuracy and precision**

- Direct incorporation of muzzle flash suppressants
  ⇨ no need for added separate "salt pills"
- Higher cook-off resistance, improved IM properties
- NG-free (safety) / non-toxic "green" formulation
- **Avoidance of critical migration problems** (plasticizers)
- Much **higher service life in A1 climatic zones** due to:
  - improved chemical and ballistic stability
  - improved compatibility

ECL® ⇨ US Mortar Range Extension Program (8 km)

Conclusions from Firing Tests May 2008 in Yuma

- Nitrochemie Extruded Composite Low-sensitivity (ECL®) Propellant has demonstrated performance improvements in current 120mm mortar system
- Thermal and chemical stability improvements result in more consistent muzzle velocity over the range of temperature environments, especially at elevated temperatures

  ➡ ***No velocity shift, consistent dispersions***

- This results in improved ballistic precision (no changes in stockpile)
- Increased energy density will compensate for heavier, higher drag projectiles
- This will eliminate the need to modify firing table and ballistic software when firing heavier or higher drag projectiles

ECL® propellants offer performance and safety benefits for future solutions

ECL Propellant Technology for 120mm Mortars

ECL® ⇨ Excellent Interior Ballistic Performance

US Mortar Range Extension Program (8 km)
Results from Firing Tests May 2008 in Yuma

145 DEG F	Wt (lb)	Range (m)	MV (mps)	TOF (sec)	Press1 (psi)	Range Std Met (m)	Range YPG Met (m)
ECL®	30.41	8458	378.9	44.76	17072	8318	8654
70 DEG F	**Wt (lb)**	**Range (m)**	**MV (mps)**	**TOF (sec)**	**Press1 (psi)**	**Range Std Met (m)**	**Range YPG Met (m)**
ECL®	30.42	8187	366.3	43.89	14416	7980	8250

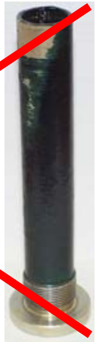
Range at STD MET just reflects removing MET effects from range values

- > 8000m range target achieved with low charge density
  - >20% “head room”, potential for further improvements on serial production basis
- This demonstrates that there is ample ballistic “head room” to compensate for heavier, higher drag projectiles

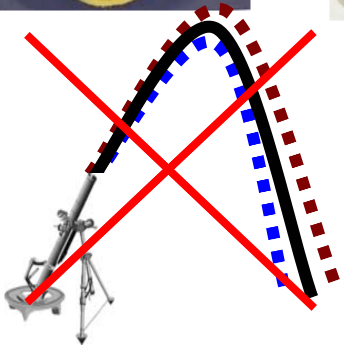
ECL® ⇨ Prolonged Service Life; Increased Safety / Reliability

- **General Aging Factors reduced by > factor 3**
  - Much longer shelf life
  - No danger of self-ignition of the propellant during storage (A1 zone)

- **Problem of plasticizer migration eliminated**
  - No deterioration of other components of the mortar grenade due to NG uptake
  - Full functionality of system maintained even after long-term storage
  - ECL® can also be used for igniter ➢ propelling technology for entire system



- **Essentially no changes of interior ballistic properties after aging**
  - Best possible precision / hit probability even after long-term storage



ECL® ⇨ Excellent Chemical Stability

Results from ARDEC investigations, June 2008: ECL and Ball Powder
Depletion of primary stabilizer after extreme aging at 71°C for 21 days

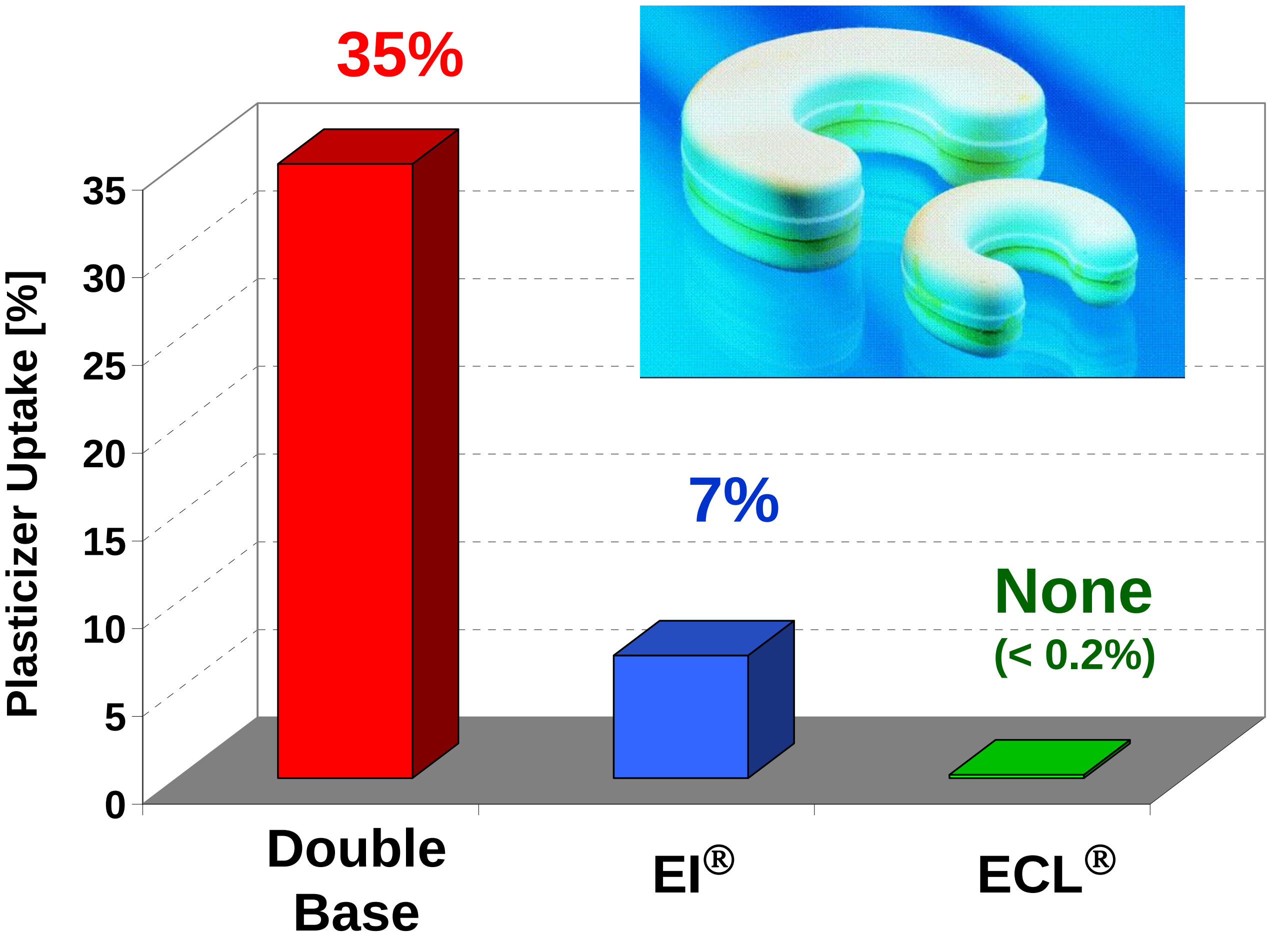
	Chemical Stability			
	ECL Propellant		M47 Ball Powder	
	RES	RES + Daughter	RES	RES + Daughter
Baseline	1.102	1.102	1.013	1.051
21 days	0.85	1.015	0.099	0.287

RES (Residual Effective Stabilizer) – virgin stabilizer material, full stabilizing potential
Daughter products – byproducts of stabilizer depletion, less effective at maintaining stability

- **Nitrochemie ECL®:** **77% primary stabilizer left, 92% total stabilizer left**
  M47 propellant: **9% primary stabilizer left, 27% total stabilizer left**
- **Nitrochemie ECL®:** **improved stability with non-NG formulation**
  - **non-toxic stabilizer**
- **M47 propellant:** **Diphenylamine (DPA) stabilizer**
  - **classified "carcinogenic"**

ECL® ⇨ Problem of Plasticizer (NG) Migration Eliminated

Equilibrium Plasticizer Uptake of Felted Fiber Container (@ 60°C)

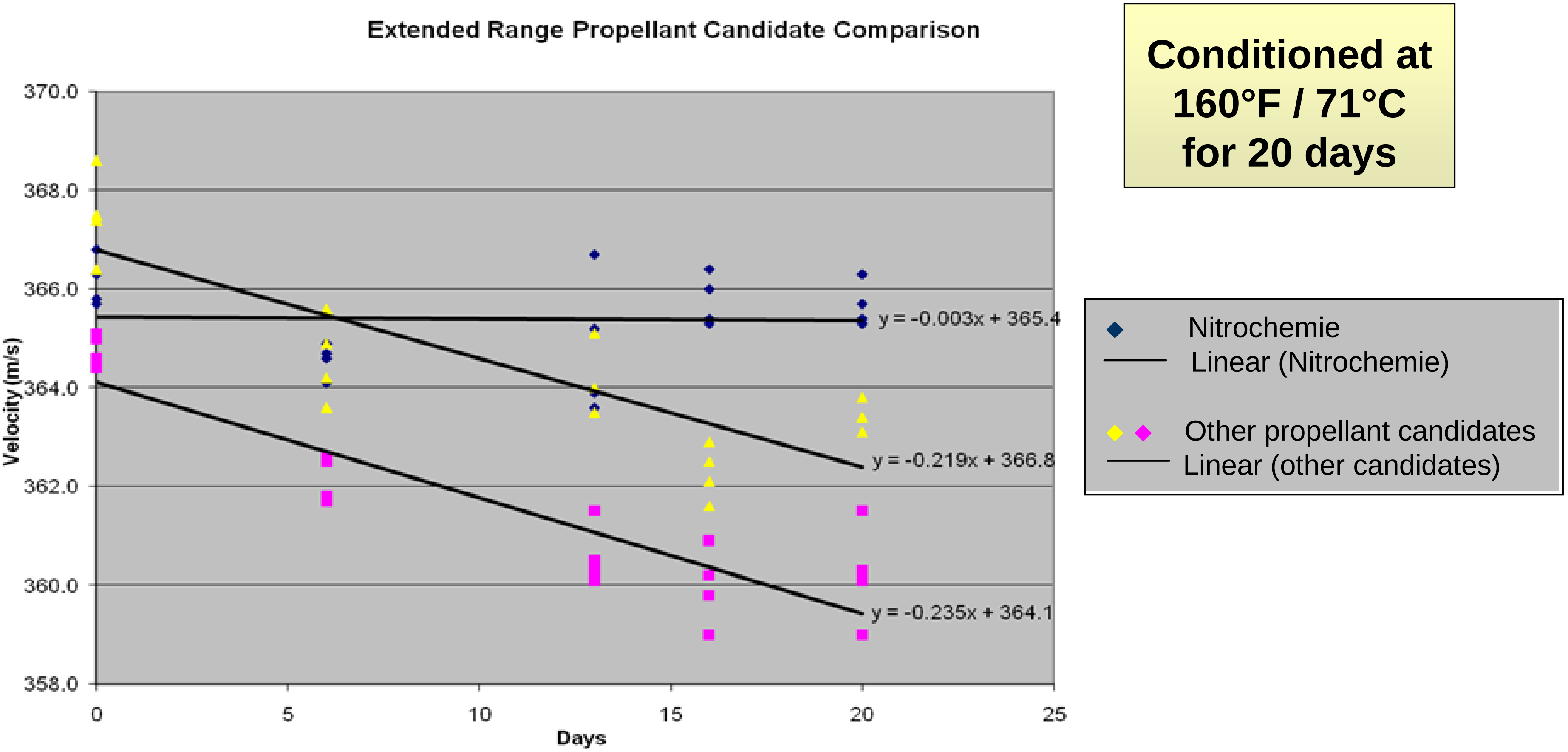


Plasticizers used in ECL® propellant do not migrate

⇨ unchanged mechanical properties of increment materials after long-term storage!!!

ECL® ⇨ Excellent Ballistic Stability

Results from Tests Yuma, June 2008



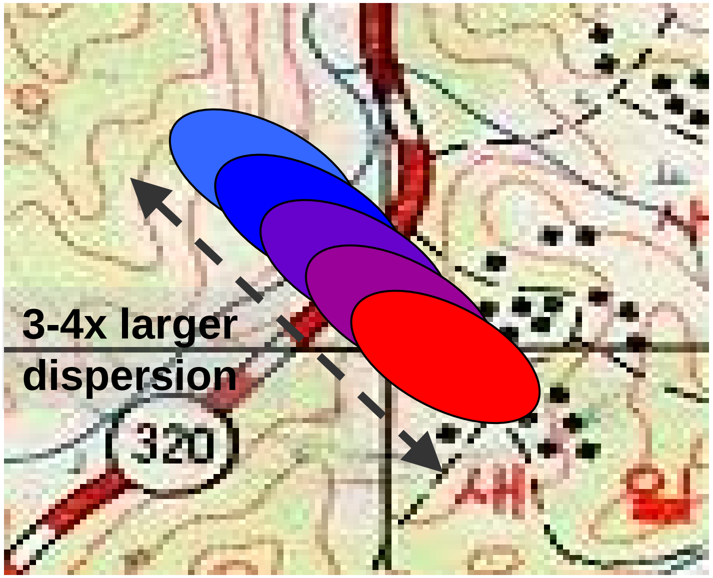
Conditioned at 160°F / 71°C for 20 days

- ⇨ **No change of muzzle velocity**
- ⇨ **No deterioration of 1st hit probability / collateral damage risk with aging**

ECL® ⇨ Excellent Ballistic Stability

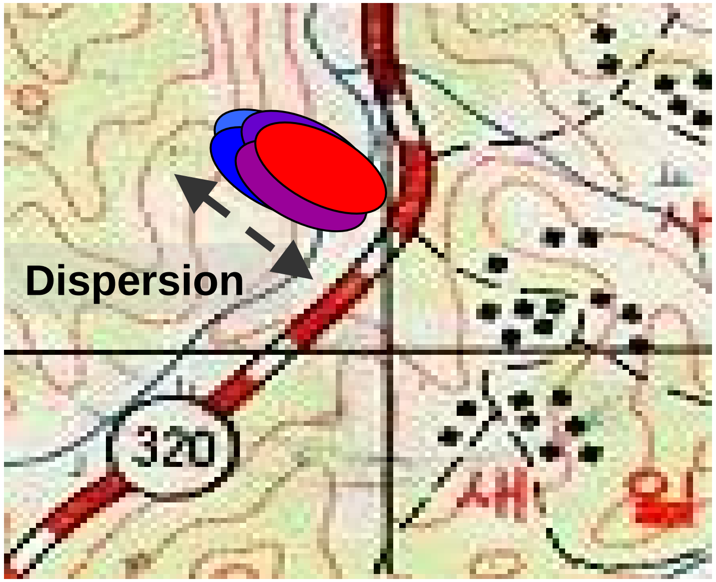
Current Propellant Solutions:

- Significant dispersion already for non-aged propellant / charge
- Velocity shift and thus impact on shot range due to aging
- Massively increased target area if ammo with various aging history is fired
- *High dispersion and collateral damage*



ECL® Propellant:

- Low dispersion for non-aged propellant / charge
- No significant change in muzzle velocity / shot distance due to aging
- Target area remains small even if ammo with various aging history is fired
- *Minimum collateral damage, reduced number of rounds*



ECL® ⇨ Incorporation of Muzzle Flash / Blast Suppressants

Firing Test Switzerland (January 2008)

Propellant with low potassium salt content

ECL® Propellant with high potassium salt content (incorporated)

ECL® propellant allows the incorporation of MF suppressant additives and thus avoiding need for added "salt pills"

Incorporation of sufficient salt load enhances the loading charge potential of propellant!

Conclusions

- **ECL® is the propellant of choice for future mortar rounds (step forward into 21st century):**
- **ECL® Propellant is well suited for any range extension program (e.g. for range extension of current or future system configurations)**
- **ECL® has the high energy density needed to compensate for future heavier or high drag projectiles and still use current firing tables**
- **ECL® is chemically and ballistically stable during long term storage at high temperatures (current mortar propellant solutions are not). This provides**
  - improved safety for our war fighters for all kind of close fights
  - superior ballistic accuracy and reduced collateral damage
  - saving of rounds and time to fire
  - longer service-life, reduced life cycle costs
- **ECL® has proven its unique overall potential in Yuma test campaign**

Acknowledgments

- **Co-workers at ARDEC, Picatinny Arsenal**
  - Bishara Elmasri, Elbert Caravaca and Brian Talley
- **Co-workers at Nitrochemie Wimmis AG**
  - Beat Vogelsanger, Peter Zoss and Heinz Jaskolka
- **Co-workers at ATK Radford Plant**
  - Steve Ritchie, Randy O'Brien and Amy Morris
- **Audience: For your Attention**

Improved LW30 Ammunition via Ignitability and Ballistic / Chemical Stability of ECL® (Extruded Composite Low Vulnerability) Propellant

Kelly Moran, Doug Messner (ATK)

Bishara Elmasri, Chester Topolski (ARDEC)

Ulrich Schaedeli, Dominik Antenen, Kurt Ryf (Nitrochemie)

NDIA Conference

44th Annual Gun & Missile System Conference

Kansas City, 7th April 2009

Benefits of ECL® Propellant

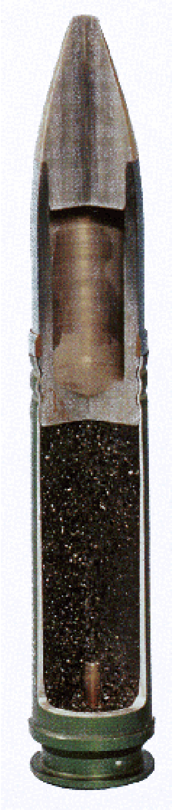
Improved Characteristic's of ECL	Translates to…
High energy density formulations High thermal conversion Tuneable performance and force	Improved ballsitc performance and efficiency Flat, tuneable ballistic profile across temperatures Improved dispersion, repeatability
No mobile plasticizers, non-nitrogylcerin	No migration of NG into cases Improved system compatability Improved safety during manufacture
Enhananced IM properties	Higher cook off temps - improved crew survival Less sensitive/no reaction to impact
Non-toxic, "green" formulation	Better for the environment Better for the user/manufacturer
Chemical stability Ballistic stability	Ammunition can be deployed to extreme climates with no degredation in performance Longer service life for ammunition




LW-30 Propulsion System Demands Redesign

Current LW-30 Ammunition Family

- M789 HEDP tactical round and the M788 TP practice round
- Fired from the M230 Gun System on the AH-64 Apache
- Propulsion: PA520 primer + 3 pellet flash tube + WC 855 BALL POWDER®

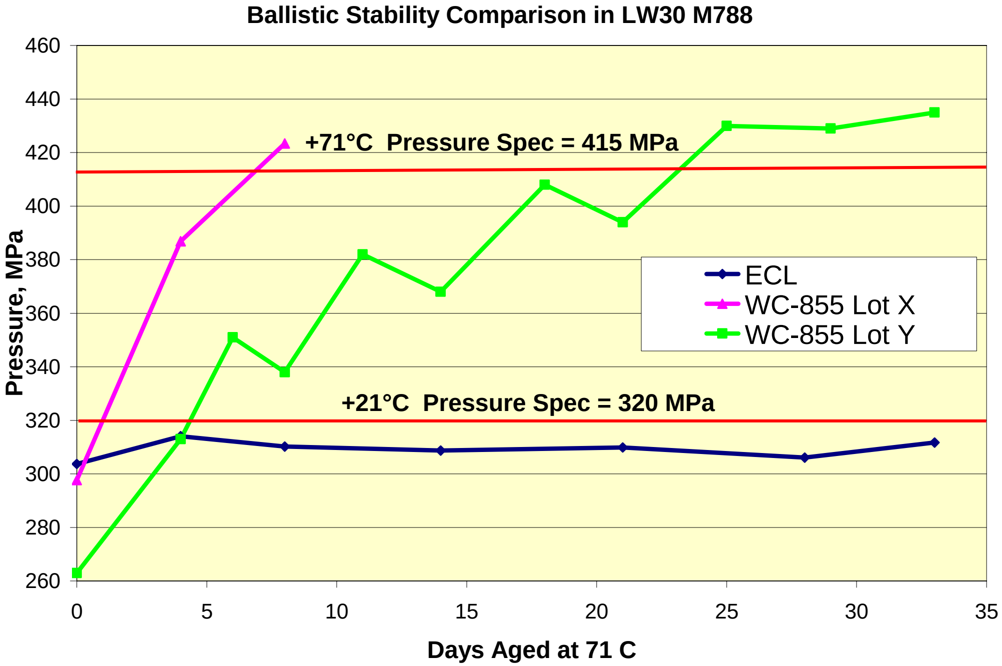


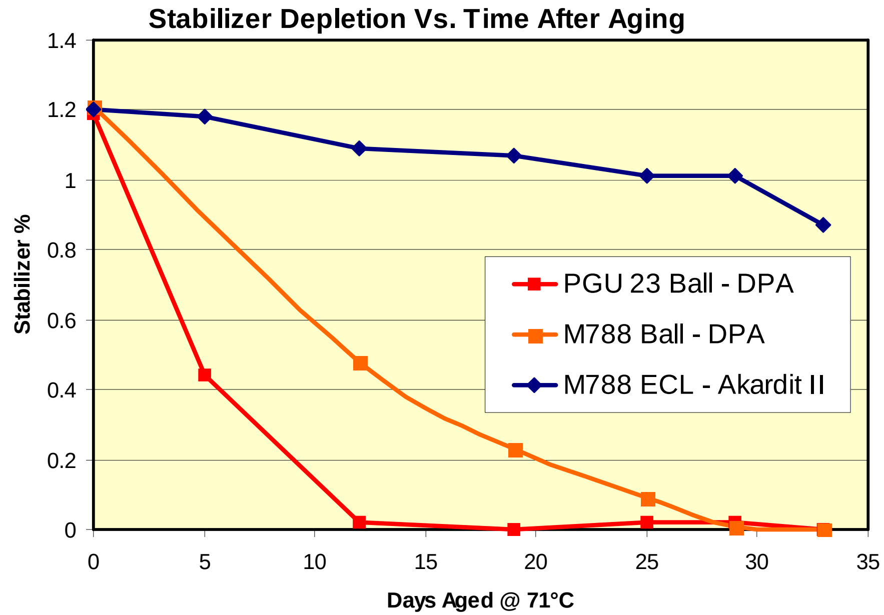
Due to In-bore detonations and hang fires resulting in weapon system failures in the field, an investigation team was established to identify root cause.

Investigation identified propulsion system weaknesses as one root cause for hang fire signature

- Propellant – current propellant found to be chemically and ballistically unstable after exposure to hot conditions
- Ignition System – nitrocellulose lacquer seal failure

ECL® Propellant Superior Stability Response





- **Large variation in ballistic stability response for WC-855 after hot temp storage**
- **Propellant lot 'X' reaches upper spec limit for pressure after 7 days at 71°C**

- **Ball propellant analyzed 0% stabilizer after 18 days at 71°C**
- **ECL propellant analyzed 1.1% stabilizer after 18 days at 71°C**

Safety Concern for User!

No change in ballistic performance of ECL after 33 days at 71°C!

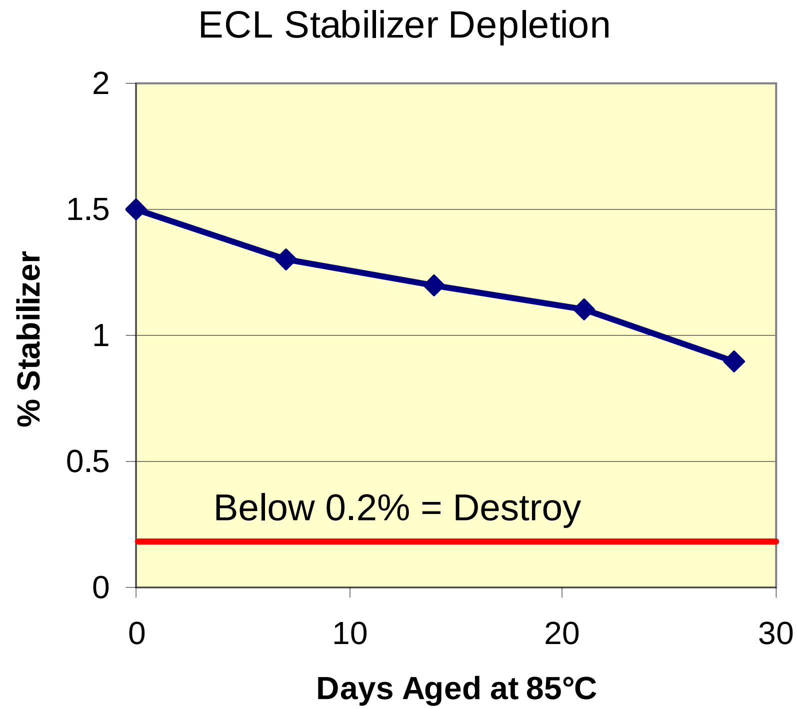
After 33 days, ECL analyzed with 83% primary stabilizer

Excellent Chemical Stability

In anticipation of more stringent aging requirements, ECL propellant was subjected to 85°C for 28 days

Time = 0

Time = 28 days



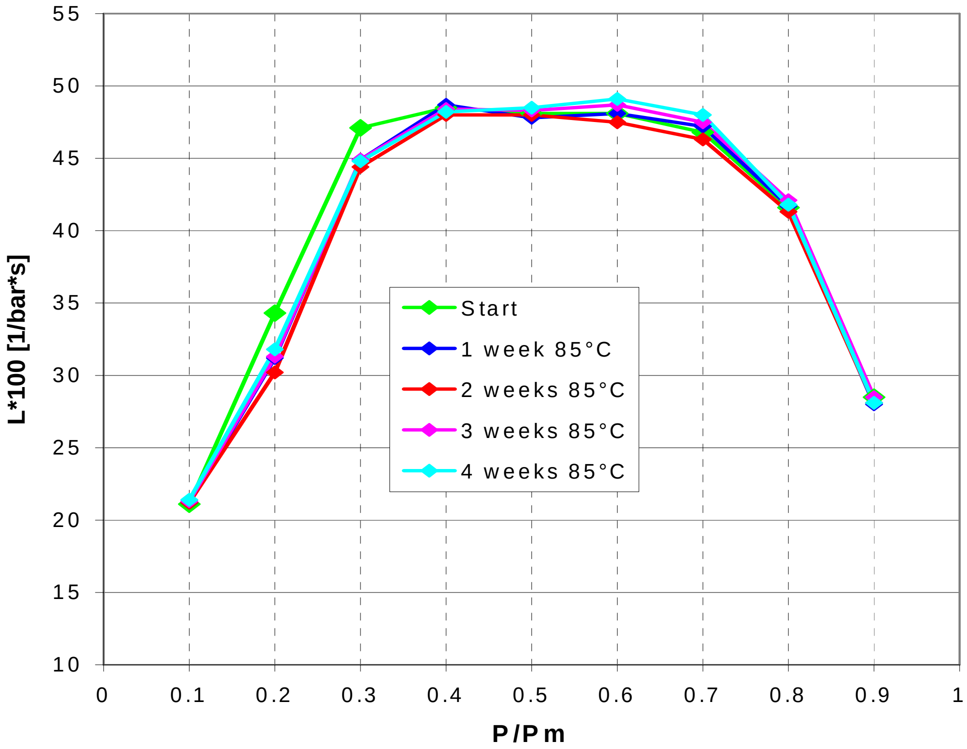
- **No physical change in appearance**
- **No gluing or tackiness of grains**
- **No RDX migration to surface**

- **After 28 days storage at 85°C , 58% primary stabilizer analyzed in ECL propellant**

Excellent Ballistic Stability

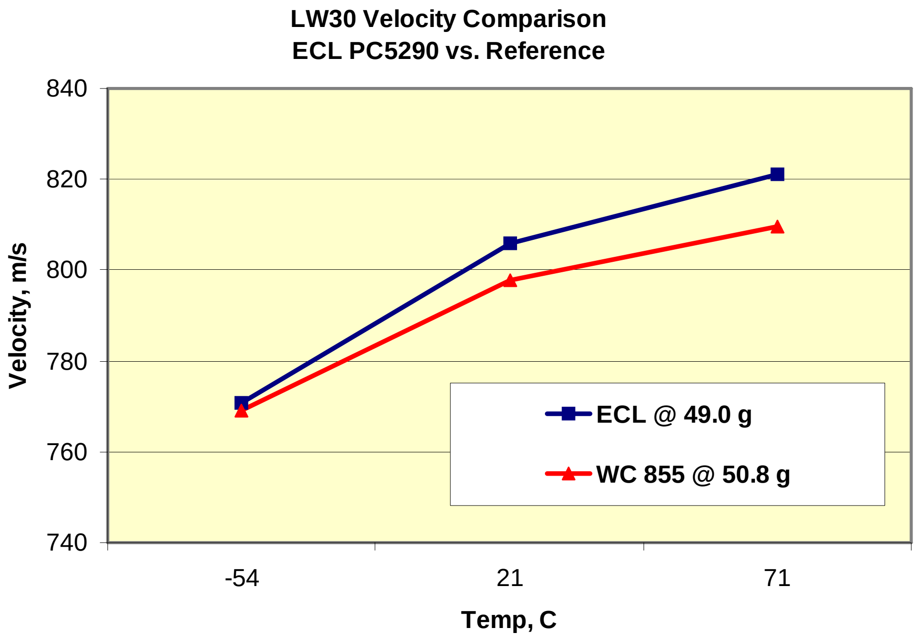
- Dynamic vivacity is a parameter of interest derived from closed bomb firing data

- Vivacity is an expression of propellant chemical composition (burn rate) and the surface area



No Degradation in Ballistic Performance in ECL Propellant After 28 Days at 85°C

Superior Ballistic Performance of ECL®

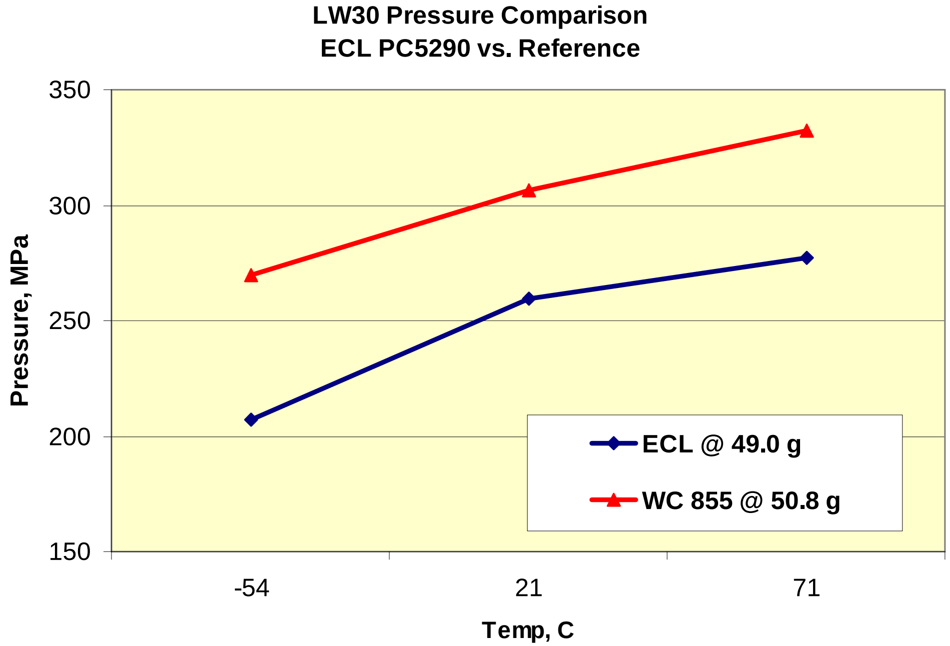


ECL Exceeds Ballistic Performance of WC 855:

- ✓ Lower Charge Weight
- ✓ Higher Velocity
- ✓ Reduced Pressure

Extra Efficiency of ECL Translates to:

- ✓ Extended Range
- ✓ Increased Lethality
- ✓ Cost Savings
- ✓ Ballistic Margin



ECL ® Propellant Offers Extended Barrel Life

Thermo-Mechanical Approach to Calculating Gun Barrel Erosion by Stein RWM

$$\text{Erosion} \sim (m_c)^{1.5} \cdot (T_{ex})^{7} \cdot (v_0)^{1.4} \cdot (p_{max})^{5}$$

m_c = Charge Mass, T_{ex} = Flame Temperature, v_0 = Muzzle Velocity, P_{max} = Peak Pressure

21°C	ECL	Ball
Charge weight, g	49.0	50.8
Flame temp, K	2880	2750
Pmax, Mpa	259.4	306.4
Erosion	6.62 E+38	1.16 E+39
Relative Erosion, %	**57**	**100**

71°C	ECL	Ball
Charge weight, g	49.0	50.8
Flame temp, K	2880	2750
Pmax, Mpa	277.4	332.4
Erosion	9.26 E+38	1.75 E+39
Relative Erosion, %	**53**	**100**

- **Relative erosivity of ECL ~ 55% of WC 855 Ball**
- **Peak gas pressure is the main driver for barrel erosion**

Ultimate LW30 : New Propellant + New Ignition

ATK
RHEINMETALL NITROCHEMIE

Action time critical to the LW30 M230 gun system

- **Rate of fire is 625 rounds per minute**

Propellant	Description	AT, ms
Reference	Std Ignition	2.70
LW30 ECL FM4285	Std Ignition	2.49
LW30 ECL FM4285	Standard primer, no flash tube	3.74
WC 855 L574	Standard primer, no flash tube	75.25
LW30 ECL FM4285	MIC primer, with flash tube	3.26
WC 855 L574	MIC primer, with flash tube	3.43
LW30 ECL FM4285	MIC primer, no flash tube	4.03
WC 855 L574	MIC primer, no flash tube	85.61

Conducted work share investigation with PM MAS to investigate alternate primer mix effects

- MIC primers are aluminum based primers
- Potential next generation lead-free "green" primer

Alternate ignition testing illustrates superior ignitability of ECL propellant

Conclusions

- **Nitrochemie ECL propellant offers superior ballistic performance in the LW-30 Ammunition Family**
- **ECL propellants are extremely stable: both ballistically and chemically even after hot temperature storage**
  - Excellently suited for extreme climate missions
- **ECL propellants are "GREEN" formulations, they do not contain toxic ingredients or mobile plasticizers**
- **ECL propellants exhibit improved IM characteristics**
- **ECL propellant formulation shows improved erosivity compared to currently fielded ammunition - service life of barrels will increase**
- **Superior ignition properties demonstrated with ECL propellant**

Acknowledgements and Questions

Co-workers at ARDEC and PM MAS, Picatinny Arsenal

- **Bishara Elmasri, Chester Topolski, Rao Yalamanchili, John Hirlinger, Anthony Cortese**

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- **Beat Vogelsanger, Tiberio Rocci**

Co-workers at ATK

- **Steve Ritchie, David Darden, Larry Douma**

Wimmis, Switzerland

Radford, Virginia

Processing of Aluminum-Based Nanothermites in a Circulating Mixer

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Energetic nanothermite research supports an effort to replace heavy metals (lead) in current military applications,

for example:

- **percussion primers (small and medium caliber),**
- **electric primers (electric matches, pyrotechnics),**
- **low energy initiators (LEI).**

Several metastable energetic nanocomposites, also known as metastable interstitial composites (MIC) or nanothermites (superthermites) were identified as the potential substitutes for currently used lead styphnate or lead thiocyanate.

Aluminum-based nanothermites (aluminum-metal oxide systems) are of particular interest in terms of their energetic characteristics.

Examples: $Al\text{-}MoO_3$, $Al\text{-}WO_3$, $Al\text{-}CuO$ and $Al\text{-}Bi_2O_3$,

Thermodynamic properties of selected thermite reactions

Thermite reaction	Q [cal/g]	Q [cal/cm^3]	Gas generation 1 atm, [g gas /g mixture]	T_{ad} [K]
$2Al + Fe_2O_3 \rightarrow 2Fe + Al_2O_3$	945.4	3947	0.0784	3135
$2Al + Bi_2O_3 \rightarrow 2Bi + Al_2O_3$	505.1	3638	0.894	3319
$2Al + MoO_3 \rightarrow Mo + Al_2O_3$	1124	4279	0.2473	3688
$2Al + WO_3 \rightarrow W + Al_2O_3$	696.4	3801	0.1463	3253
$2Al + 3CuO \rightarrow 3Cu + Al_2O_3$	974.1	4976	0.3431	2843

J.A. Puszynski, C.J. Bulian, J.J. Swiatkiewicz, J. of Propulsion and Power, Vol. 23, No. 4, 698-706, (2007).

Distinct characteristics of nanothermites:

1. **Nanothermites consist of at least two reacting component (fuel and oxidizer);**

2. **Combustion reaction rate of the nanothermite mixtures strongly depends on reactant's particle size and particle intermixing;**

3. **Energy release can be tuned by choice of the reactive components.**

Characteristics 2 and 3 are relevant specifically to the percussion primer and other types of initiators.

Metastable energetic nanocomposites (nanothermites) are difficult to process safely due to their sensitivity to friction and electrostatic discharge (ESD).

A typical small scale preparation of such powders involves mixing of nano-size reactant powders in an inert solvent (wet mixing). After sufficient mixing of a slurry, the solvent is evaporated and solid mixture is dried, resulting in a loose powder of the nanothermite.

Any handling of nanothermite powder must be carried out with extreme caution; for example, an ESD discharge at energy level of a fraction of μJ can ignite loose powder of Al-Bi_2O_3.

Nanothermite System	ESD ignition energy (mJ)
Al-Fe_2O_3, powder	0.113
Al-MoO_3, powder	0.050
Al-Bi_2O_3, powder	0.0001
Al-Bi_2O_3, granule	1.5

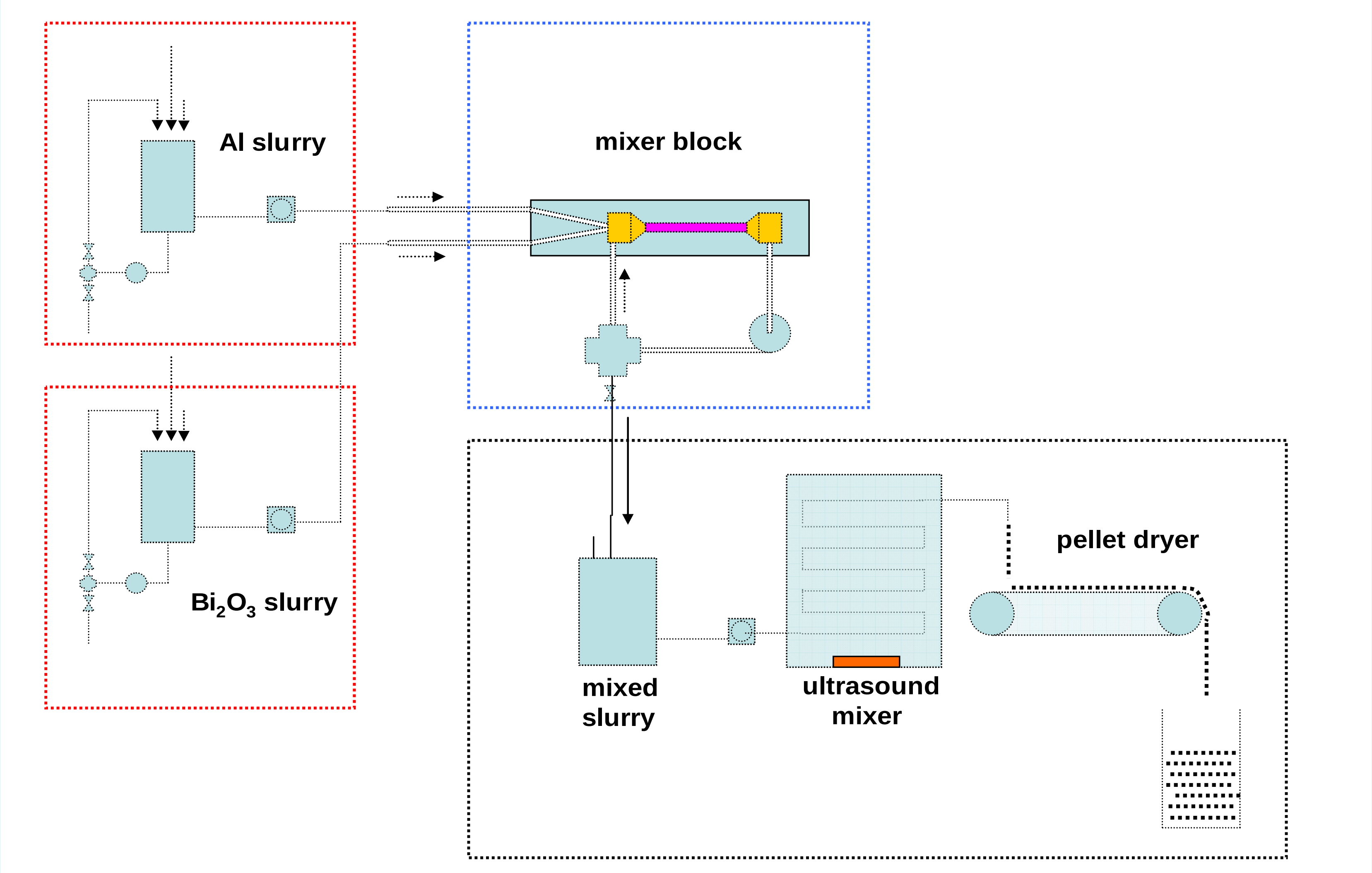
Wet mixing in organic solvents and loading operations are limited to small quantities performed in a batch mode (a few grams). These processes are difficult to scale-up due to possible stratification of slurry and the VOC concerns.

Need for design of a process of nanothermite wet mixing and loading which would support:

- **flexibility of mixing various components,**
- **choice of the solvent (including specifically water),**
- **yield larger quantities of product (hundred grams/day or more).**

A new mixing process of the nanothermite components in a water slurry was developed and tested in the Innovative Materials and Processes LLC. The developed process uses a circulating mixer that continuously operates during the mixing and dispensing cycles.

The proposed scheme of continuous mixing in a in-line mixer with recirculation of a slurry combined with ultrasonic agitation.



1. Water-based mixing process is inherently safe.
2. Formation of compact granules has ESD safety advantages.
3. Dense slurry can be dosed directly to the application (primer cup).

Mixer implementation:

Tubing pumps: variable flow rate, minimal dead volume in tubing, easy disposal and deactivation of residual slurry.

Tubing: broad range of sizes, various materials (Silicone, Tygon, PFTE, Norprene).

In-Line Static Mixer: 3/16" OD stainless steel tube and various number of helical elements of the mixing insert.

Pressure drop on tested mixer was less than 10 psi at maximum flow rate of 400 ml/min for the most dense slurry of Al-Bi_2O_3 in water.

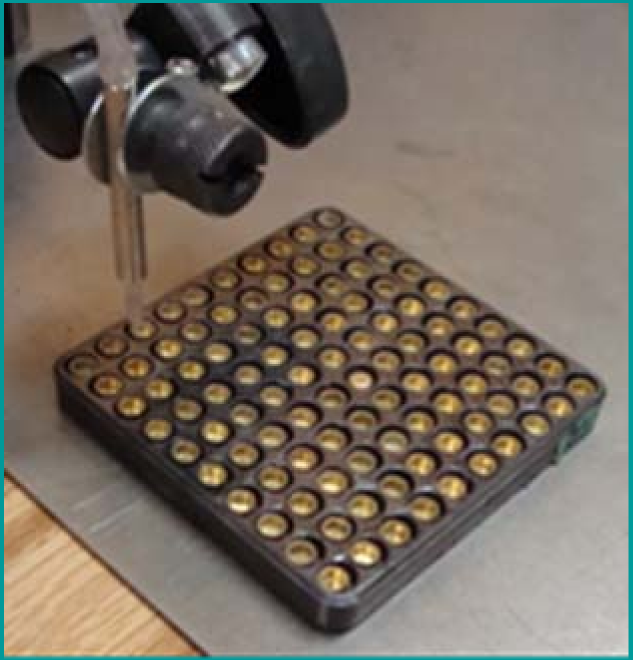
Assembled mixer and metering modules used for preparation of $Al\text{-}Bi_2O_3$ nanothermite mixture.

The system is capable to produce 600 small caliber percussion primers during a 30 min cycle.

Total amount of dry nanothremite is ~23 g, about tenfold increase over the laboratory batch scale.

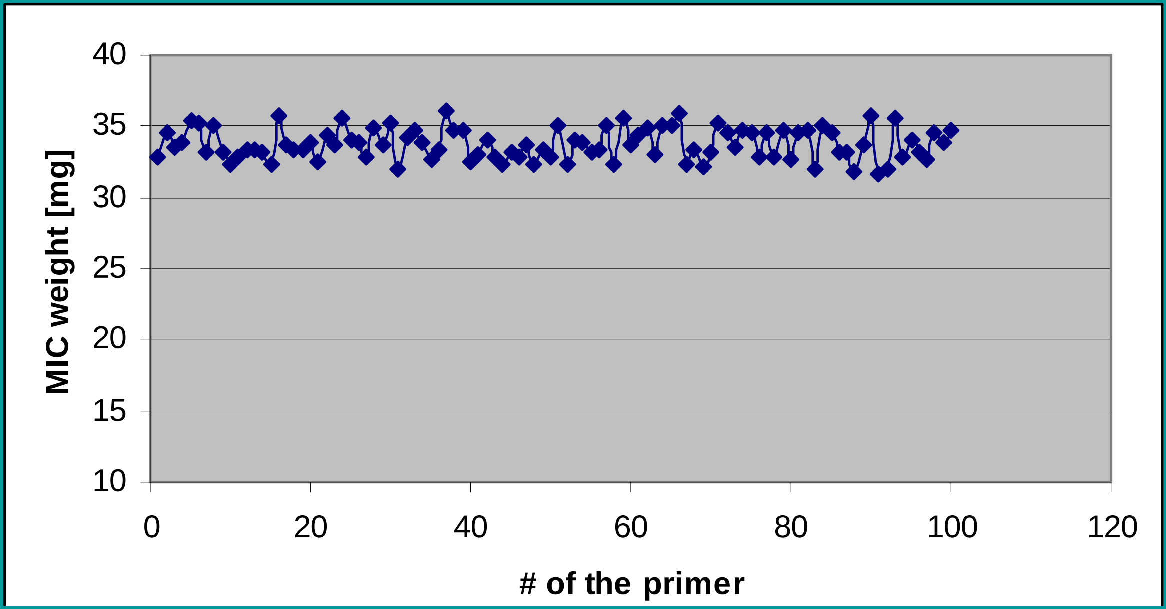
Further increase of the throughput can be achieved by the increase of the mixer reservoir volume (from 30 ml to up to 300 ml in this implementation).

After 30 minute of mixing and ultrasound agitation the slurry is ready for metering.



A tray of 100 cups before filling with the nanothermite slurry.

Weight of Al-Bi_2O_3 primer mixture after dosing slurry into small caliber primer cups



Average weight is 33.7 mg with the STD of 1.3 mg.

Impact sensitivity test of the assembled primers:

50% probability to fire: height 5.15 ± 0.51 inch

using ball drop test (1.94 oz)

Mixing of Al-(Fe_2O_3, Bi_2O_3) nanothermite system in water.

A slurry containing Al-Fe_2O_3 nanothermite in water was mixed using circulating mixer. This slurry was then combined with a Al-Bi_2O_3 suspension mixed earlier, while the mixer was continuously running.

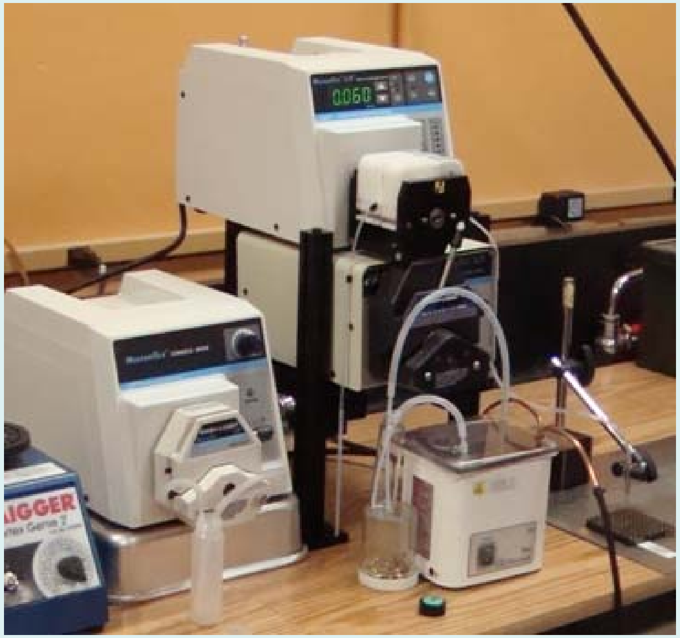
After 15 minutes of homogenizing in the in-line mixer and during ultrasound agitation the liquid suspension was dosed as 5μL droplets to form pellets on the PFTE surface (after drying).

This nanothermite mixture contains iron oxide and bismuth oxide in the weight ratio of 2.33.

By mixing various amounts of the premixed slurries any other oxide ratio can be obtained.

Mixing in Anhydrous Solvent

Composition containing Al, Fe_2O_3, and SiO_2 (as diatomaceous earth) is similar to one used as an ignition mix in pyrotechnic devices. This mixture does not contain nanosize powders but its preparation in the circulating mixer is a good example of the mixer application flexibility. Mixing was carried out in anhydrous isopropyl alcohol.



Advantages:

- **mixing is carried out in practically closed system; there is no loss of the solvent during mixing,**
- **tubing pump facilitates quick discharge of the slurry onto a drying pan, avoiding stratification of the components.**

Disadvantage:

- **expecting very viscous suspension to deal with, it was necessary to use additional tubing pump in order to premix the components before feeding slurry into the circulating mixer.**

Mixing in Anhydrous Solvent

Al-MoO_3 nanothermite components are typically mixed in an inert solvent like hexane. Hovever, for mixing Al-MoO_3 nanothermite components and nitrocellulose binder the preferable solvent is 1:1 by volume mixture of acetone and isopropyl alcohol.

Aluminum and molybdenum trioxide nanopowders were suspended in acetone/isopropyl alcohol containing dissolved nitrocellulose and mixed in the circulating mixer with ultrasound agitation for 30 minutes.

The resulting suspension was stable for long period of time (months) and could be used for making coating on surfaces. It is also suitable for preparation of electrical igniters.

Conclusions:

- Off-shelf tubing pumps (peristaltic pumps) were tested in several applications for mixing and metering of the nanothermite slurries in water as well as in anhydrous organic solvents.

- Combining simultaneous action of the in-line mixer and the ultrasound field allows very effective mixing of particles in the slurry for nanothermite systems based on aluminum – oxides (Bi_2O_3, Bi_2O_3/Fe_2O_3, and MoO_3) and micron size Al-Fe_2O_3/SiO_2 suspended in a solvent.

- Impact sensitivity tests conducted on the standard primer mixture (Al-Bi_2O_3) confirmed that new mixing method lead to the same primer performance as primers obtained from small size batch mixing.

- The method of circulating mixing of the nanothermite components in water can be easily scaled up from the current minimal volume of 30 mL to 300 mL, using the same pump system, by only increasing size of the mixing vessel and tubing diameter.

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South Dakota School of Mines and Technology
Rapid City, South Dakota

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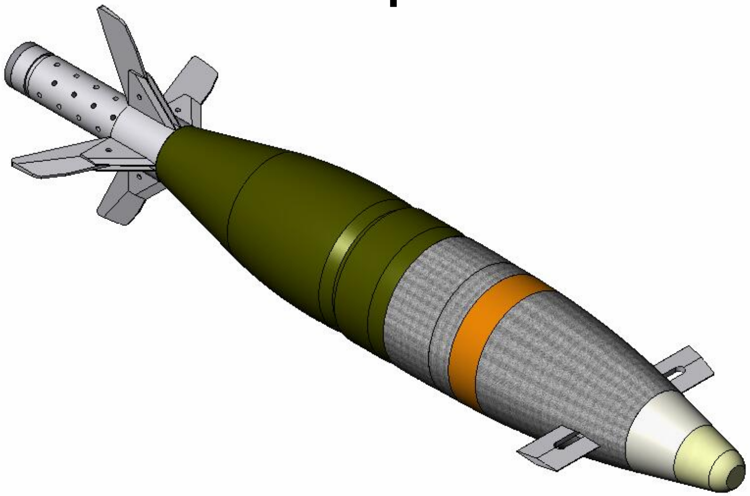
Flight Controlled Mortar
FCMortar

NDIA Guns & Missile Systems Conference
6-10 April 2009



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NAVSEA WARFARE CENTERS DAHLGREN

Flight Controlled Mortar
FCMortar

- What is FCMortar?
  - Guidance Kit for 81mm HE ammunition
    - Adds precision capability to M821A1/A2 & M889A1/A2 Family of Ammunition
    - Upgrade performed at Depot level
- Why FCMortar?
  - 81mm mortar systems currently area fire weapons
    - Can't provide fire support in confined areas
    - No precision capability
  - Brings light-weight precision capability to the company/platoon level
    - When utilized within USMC Enhanced Company Operations (ECO) framework
    - Timely, Organic Fire Support

Does not replace existing 81mm Mortar Inventory

NAVSEA WARFARE CENTERS DAHLGREN

Flight Controlled Mortar
Projected Capabilities

- Precision Delivery
  - GPS & Terminal Seeker
- Access to new/difficult terrain types
  - Urban (MOUT), Canyons, Mountains, Reverse Slope
- Built on existing mortar capabilities
  - Retains fuzing functions & propulsion system
  - Comparable engagement ranges
- Cost Driven solution
  - $3,200 - $5,000 AUPC

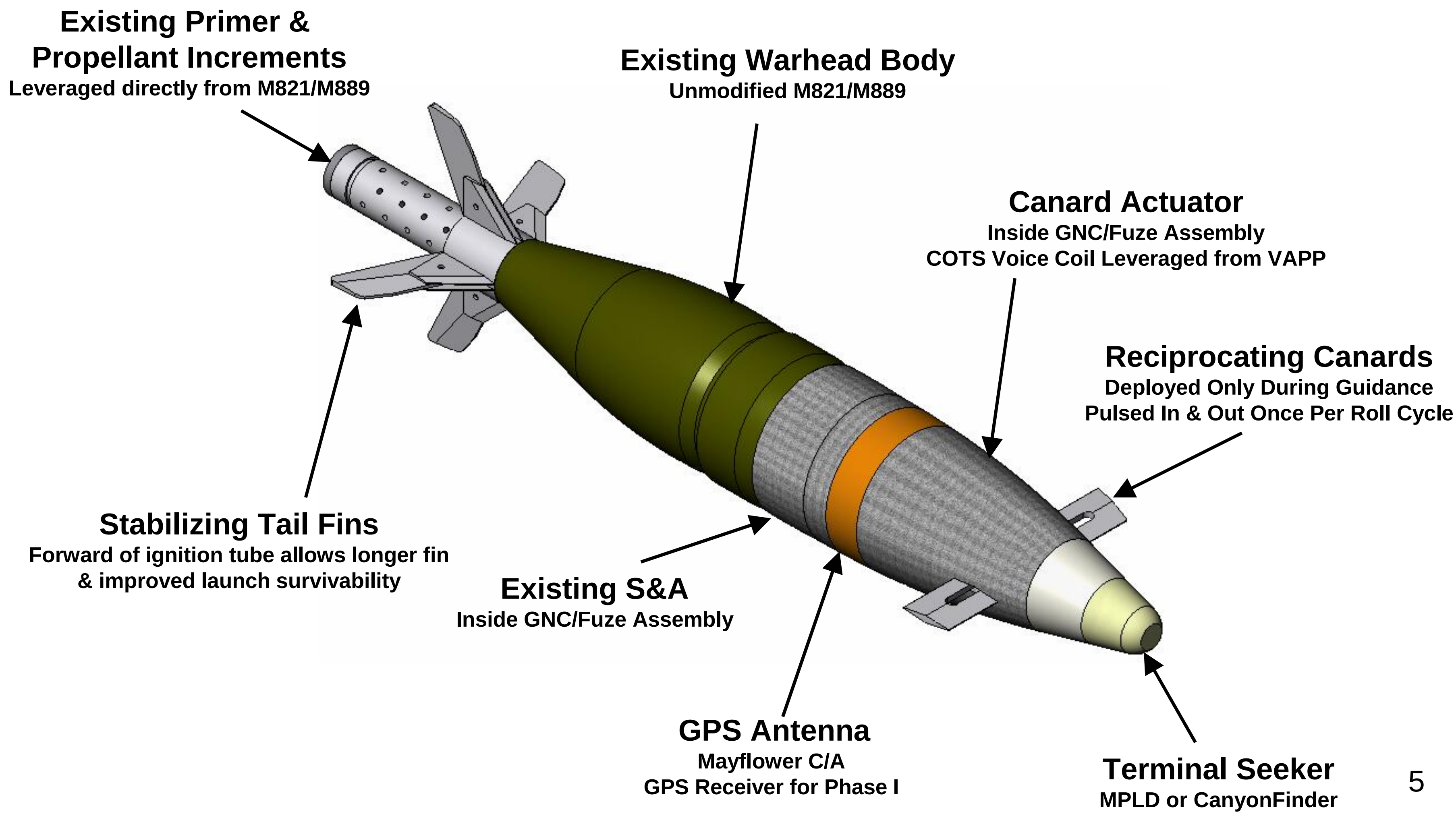
NAVSEA WARFARE CENTERS DAHLGREN

Flight Controlled Mortar
Two Products in One

- Smart Mortar (SMortar)
  - GPS Based Guidance Kit for 81 & 120mm mortars
  - Conceived by ARL as low-cost alternative to PGMM
  - Leverages technologies developed under Very Affordable Precision Projectile (VAPP) program (ARL/ARDEC/PM-CAS)
  - Could be transitioned as GPS only guidance if desired

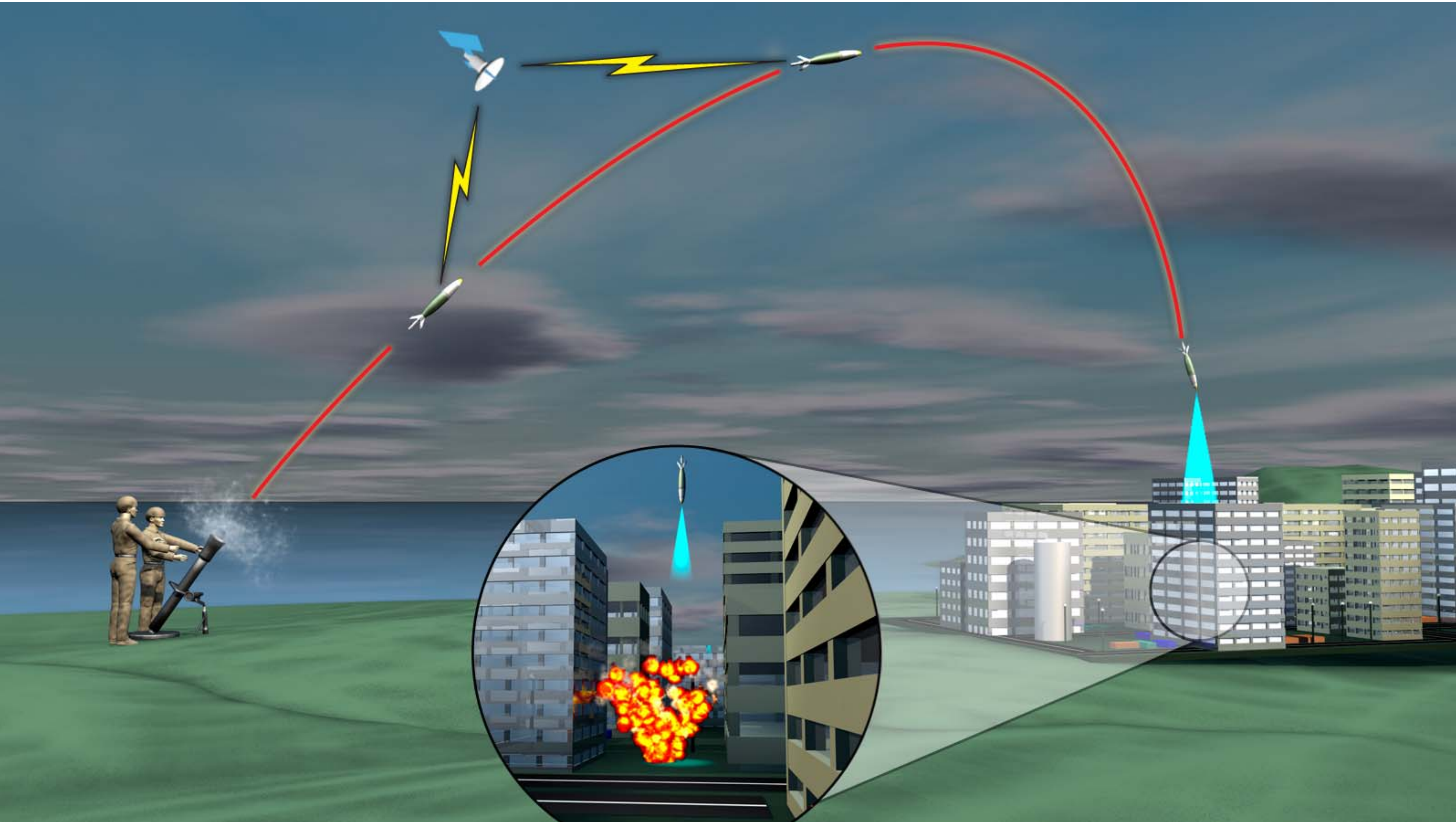
- CanyonFinder
  - Terminal Seeker for FCMortar
  - Minimizes TLE & GPS errors during terminal phase of guidance
  - Risk reduction effort with Micro-Pulse Laser Designator (MPLD)
  - Currently in source selection
  - Modular design occupying minimal real estate
    - Technology easily transportable to other weapons

Flight Controlled Mortar
Baseline Design Overview



Distribution Statement A

Flight Controlled Mortar
Urban (MOUT) Mission



Flight Controlled Mortar
DoD Development Team

- Sponsor
  - Office of Naval Research, Code 30 Fires
- Principal Investigator
  - Naval Surface Warfare Center Dahlgren Division
    - Code G33 – Precision & Advanced Systems Branch
- Guidance Kit Development, Integration, & Testing
  - Army Research Lab, Aberdeen Proving Ground
    - Advanced Munitions Concepts Branch
- Terminal Seeker Development
  - Micro-Pulse Laser Designation
    - Naval Surface Warfare Center Dahlgren Division
      - Code G31– Expeditionary Weapon Systems Branch
        - » Targeting Engagement Systems Center of Excellence (TESCE)
  - CanyonFinder
    - TBD – Currently in Source Selection

Flight Controlled Mortar
Program Schedule

- Phase I (FY09-11)
  - Development of system architecture
    - Sub-system development & demonstration
  - Terminal seeker technology maturation
  - GPS only guided flight & trajectory shaping demonstrations

- Phase II (FY12-13)
  - Terminal Seeker Integration
  - Guided flight & trajectory shaping demonstrations w/ Terminal Seeker
  - Capstone Demonstration
    - End-to-end demonstration including external systems
    - Intended to be as realistic as feasible
  - Transition to Acquisition

Technical Maturity will be gauged through a series of 21 demonstration events

Flight Controlled Mortar
Airframe Wind Tunnel Test (WT1)

- First Demonstration Event
  - ARDEC Sub-Sonic Wind Tunnel, Picatinny Arsenal
    - 9-12 February 2009
- Validated most aerodynamic predictions
  - Supports simulations showing vertical approach & range extension capabilities
  - Need minor design change to enhance static margin

Flight Controlled Mortar
Integrated Mortar System Family of Programs

- M252E1 Light-Weight Mortar System
  - Reduces weight by 1/3
- Extended Range Mortar Ammunition (ERMA)
  - Advanced propellants
    - Increased Initial Velocity for Extended Range
    - Improved IM characteristics
- Marine Corps Mortar Fire Control System (MCMFCS)
  - Integrated Mortar Section, Automated FDC capability
  - Reduced Mortar Laying Time
  - Future space claim for FCMortar Mission Setter
- Distributed Operations Precision Engagement (DOPE)
  - Local Wind Sensing
  - Initial Velocity Sensing

NAVSEA WARFARE CENTERS DAHLGREN

Flight Controlled Mortar
Summary

ARL

- Supplements existing 81mm mortar inventory with precision capability
- Allows engagement of targets in previously inaccessible terrain
- Lower cost & more mobile alternative to existing precision fire support systems
- Supports Enhanced Company Operations (ECO) Framework

RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Trajectory Simulations of the Ejected Vent Plugs during Premature Fuze Detonation of the 81mm, M879 Full Range Practice Mortar Cartridge

Seungeuk Han

AMSRD-AAR-MEM-A

Aeroballistics Division

Munitions Systems & Technology Directorate

BACKGROUND

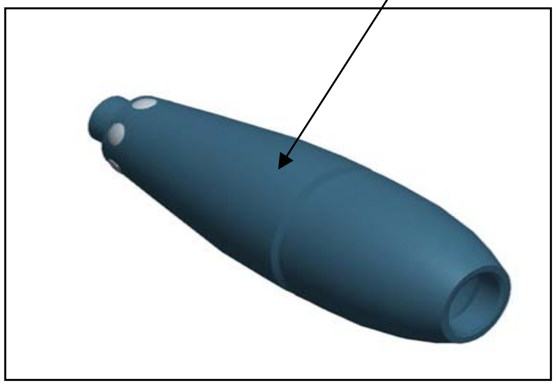
- The 81mm, M879 Full Range Practice Mortar Cartridge (FRPC) has six (6) steel plugs (0.5 inch diameter each - uncompressed) located on the boattail that are designed to eject and vent out pyrotechnic smoke generated by the fuze upon its function.
- The fuze can function prematurely; as close as 5 feet slant range from the gun muzzle.
- Although the possibility of occurrence is extremely low, soldier safety in the event of premature fuze functioning was studied.

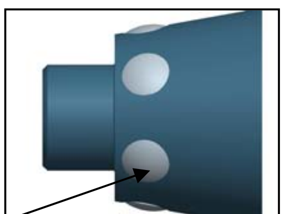
BACKGROUND (Continued)

- There are six (6) identical steel plugs on the body:
  - Thickness = 0.062 in (1.575 mm)
  - Weight = 0.00342 lbm (1.55 g)
  - Diameter = 0.5 in (12.7 mm)
- The internal pressure inside the projectile body is 6,000 psi.
- Projectile launching conditions:
  - Propellant Charge 0 (muzzle velocity of 216.5 ft/sec)
  - QE of 75 degrees

SYSTEM DESCRIPTION

81mm, M879 Steel Body



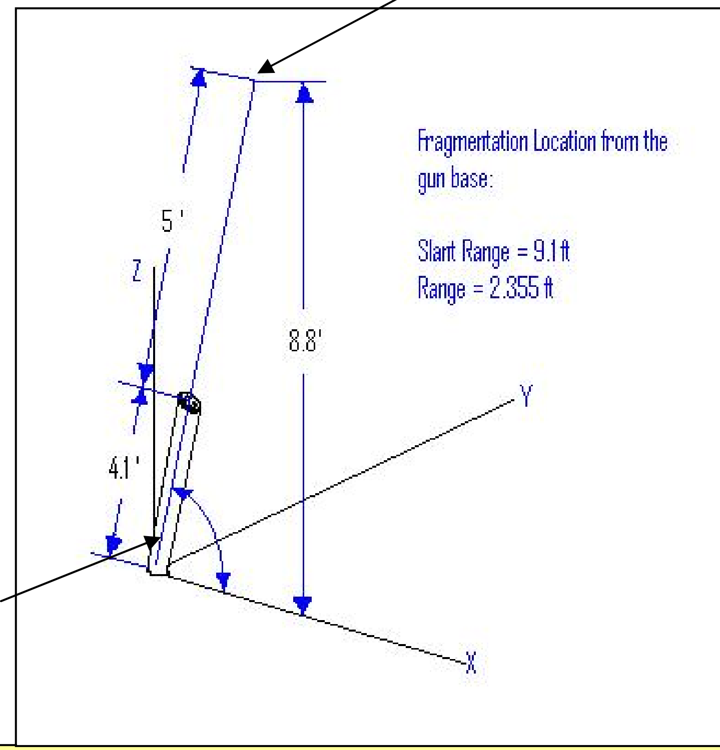


Steel Plugs

Boattail Section

Gun Tube

Fuze Function Location



Initial Conditions for the Plug Simulation

CONCERNS

- Do the plugs hit an average height soldier (5’,6” – 6’, 2”).
- If the plugs hit anything direct at ejection, will it hit with greater impact energy than the Less-Then-Lethal (LTL) criteria of 58 ft-lb?
- If the plugs hit indirectly by falling to the ground, will it hit with greater impact energy then the LTL criteria of 58 ft-lb?
- If the plugs falling, will it hit the vulnerable human body parts like ears and eyes, etc?

METHODS OF SIMULATIOINS & ASSUMPTIONS

- Trajectory of the plugs were estimated by using 3 DoF computer program.
  - Initial conditions of the plugs were set at the projectile conditions at 5 ft slant range from the muzzle.
  - Constant drag coefficient had been used.
  - The plug was assumed tumble throughout the entire trajectory.

- An equivalent aerodynamic drag coefficient and its respective reference area were estimated for the simulation.
  - **A_{eq} = 0.126 in^2**
  - **CD_{eq} = 2.0**

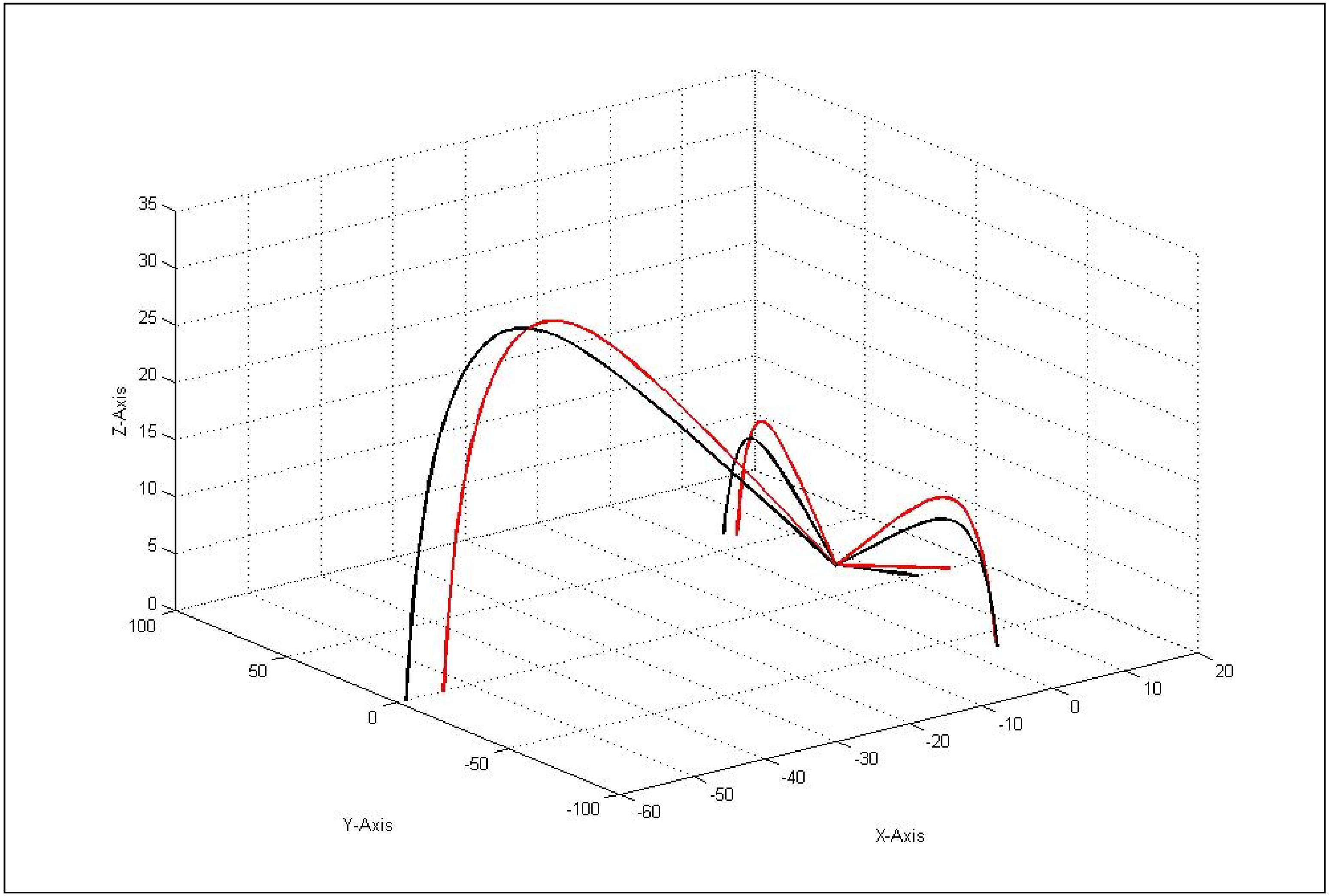
CONDITIONS OF THE SIMULTATIONS

- Internal chamber pressure due to the fuze detonation is up to 6,000 psi.
- The firing condition of charge 0 at QE of 75 degrees is assumed to be the worst case.
- The rectangular coordinate system had been used.
- The plugs are tumbling during their entire trajectories.
- There is no energy loss during the plug ejection process.

PLUG EJECTION VELOCITY ESTIMATIONS

- The ejection velocity for this pressure is estimated at 1070 ft/sec (326 m/sec), which is higher then the 58 ft-lb cutoff velocity of 1047.5 ft/sec for the plug.
- According to the Lam's Equation, a force estimation equation to press fit a pin, the lowest pressure the plug will eject is 3800 psi.
- The ejection velocity for this pressure is estimated at 810 ft/sec (247 m/sec)

PLUG TRAJECTORIES



Results

- The plugs are ejected at 8.8 feet which is beyond the reasonable heights of soldiers enlisted in the US Army (about 6 feet).
- All plugs behind and to the side of the gun position are falling near vertically with the velocities approx 36 – 41 ft/sec (i.e. ≈ 0.1 lbs-ft).
- All plugs front of the gun position are hitting the ground directly with 300 – 520 ft/sec (eq. 4.8 – 14.3 lbs-ft), but no one allowed to be in this area during firing.

CONCLUSIONS

- Possibility of the plug hitting the operator is extremely low.
  - Fuze detonates beyond the reasonable heights of soldiers.
  - No one allowed to be in front of the gun during firing.
- Kinetic energy of the plug hitting the operator is negligible compare to the LTL criteria of 58 ft-lbs.
  - Each plug can reach the ground around 40 ft/sec which is about 0.1 ft-lbs.
- Impact angle of the plugs on the operator near the ground level is vertical.
  - The plugs behind the gun position are falling to the ground near vertical (90 degree from horizon), it is not likely to impact the vulnerable human body parts like ears, eyes, and mouth.

POCs

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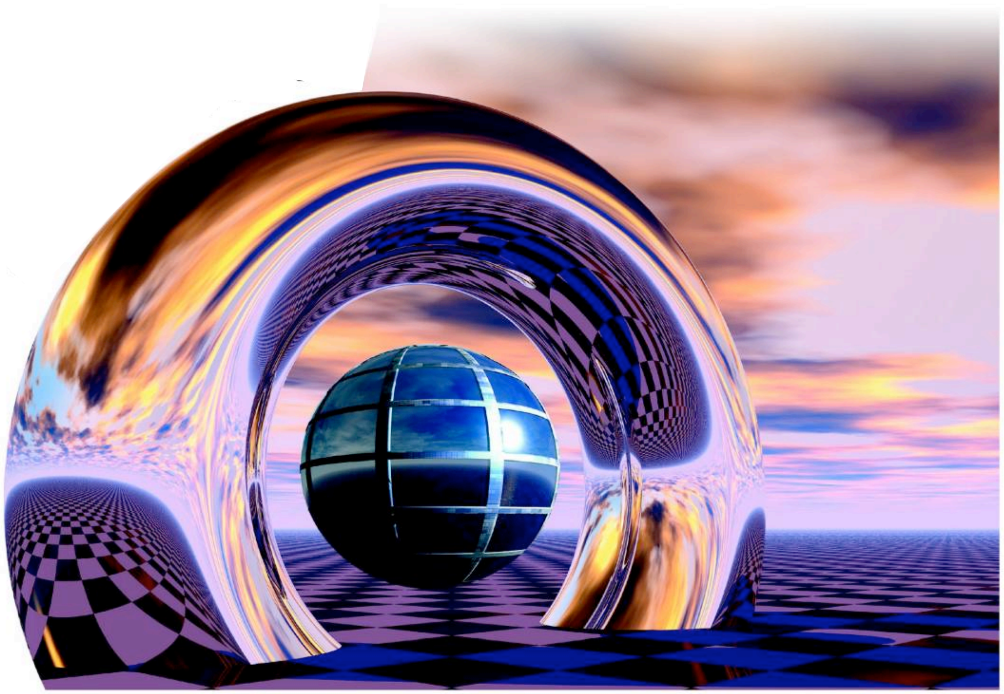
Combustion Light Gas Gun

CLGG



Progress Update
April 8, 2008

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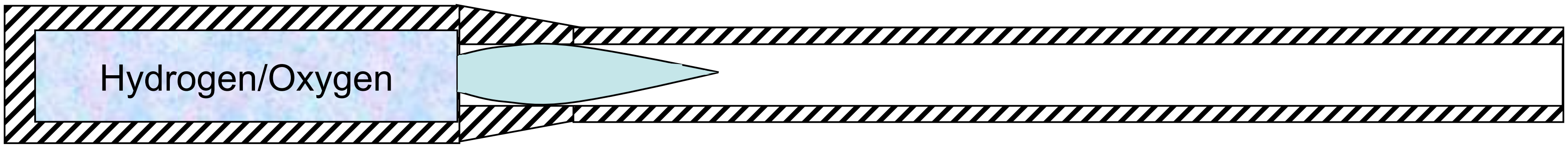
CLGG Physics

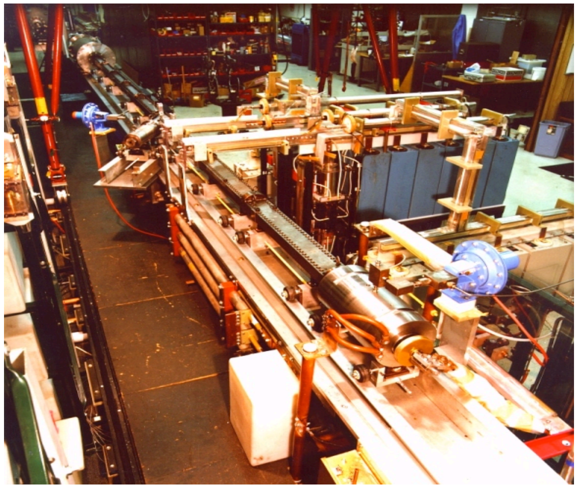


The lighter propellant gases keep the pressure behind the projectile higher

CLGG Chronology

Time

1993	1995 →	2007 →



Bore Size

16 mm	45 mm	155 mm

Kinetic Energy Levels

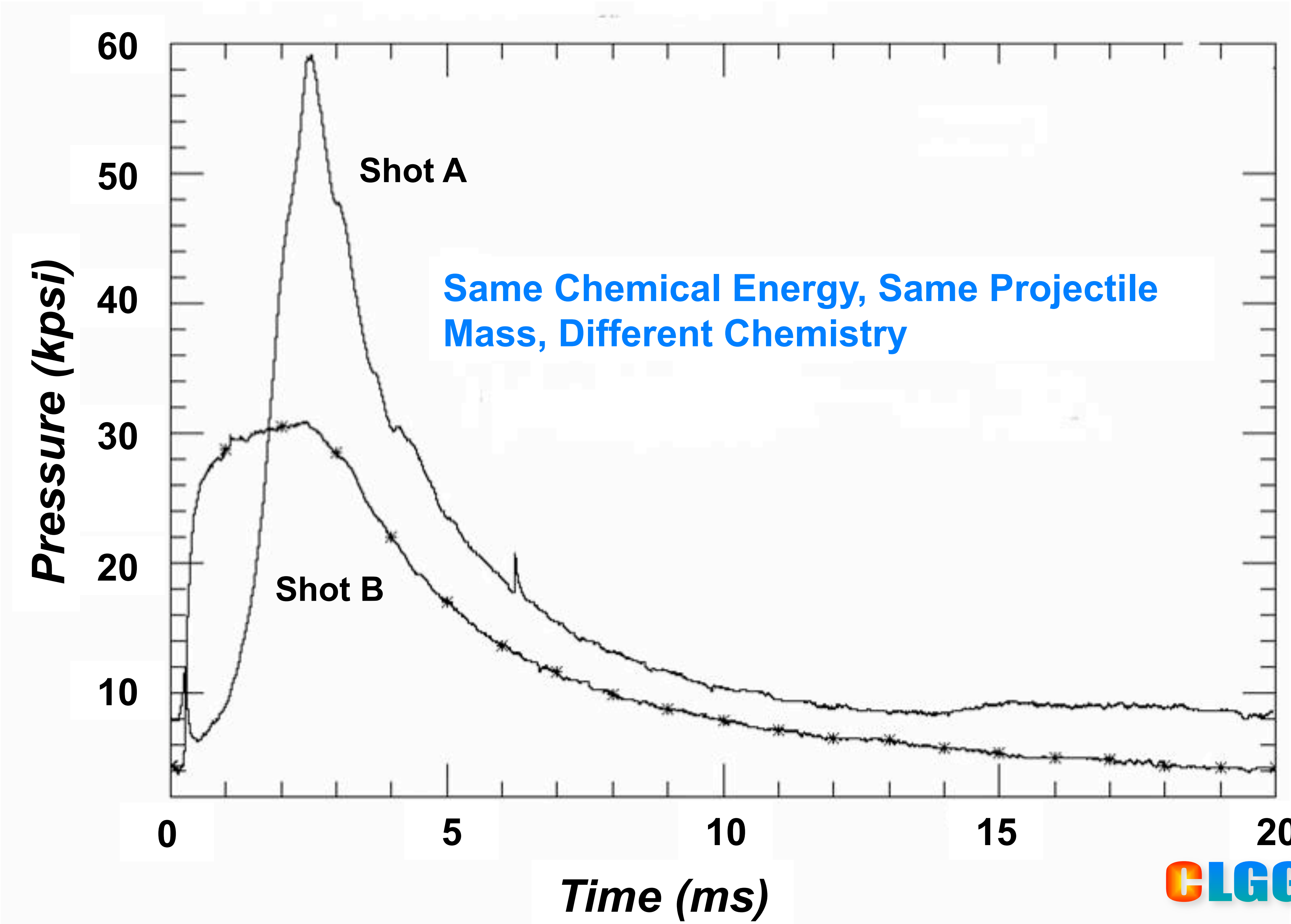
kJ's	Few MJ's	Tens of MJ's

CLGG

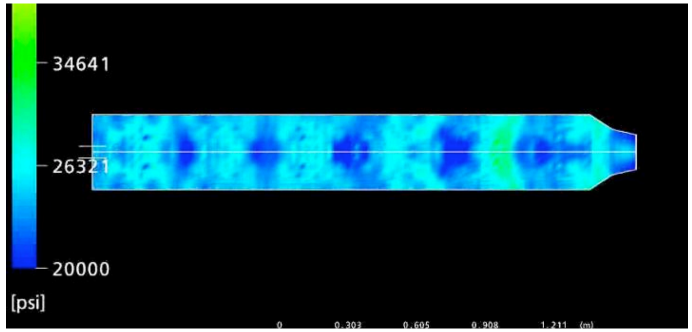
CLGG Benefits

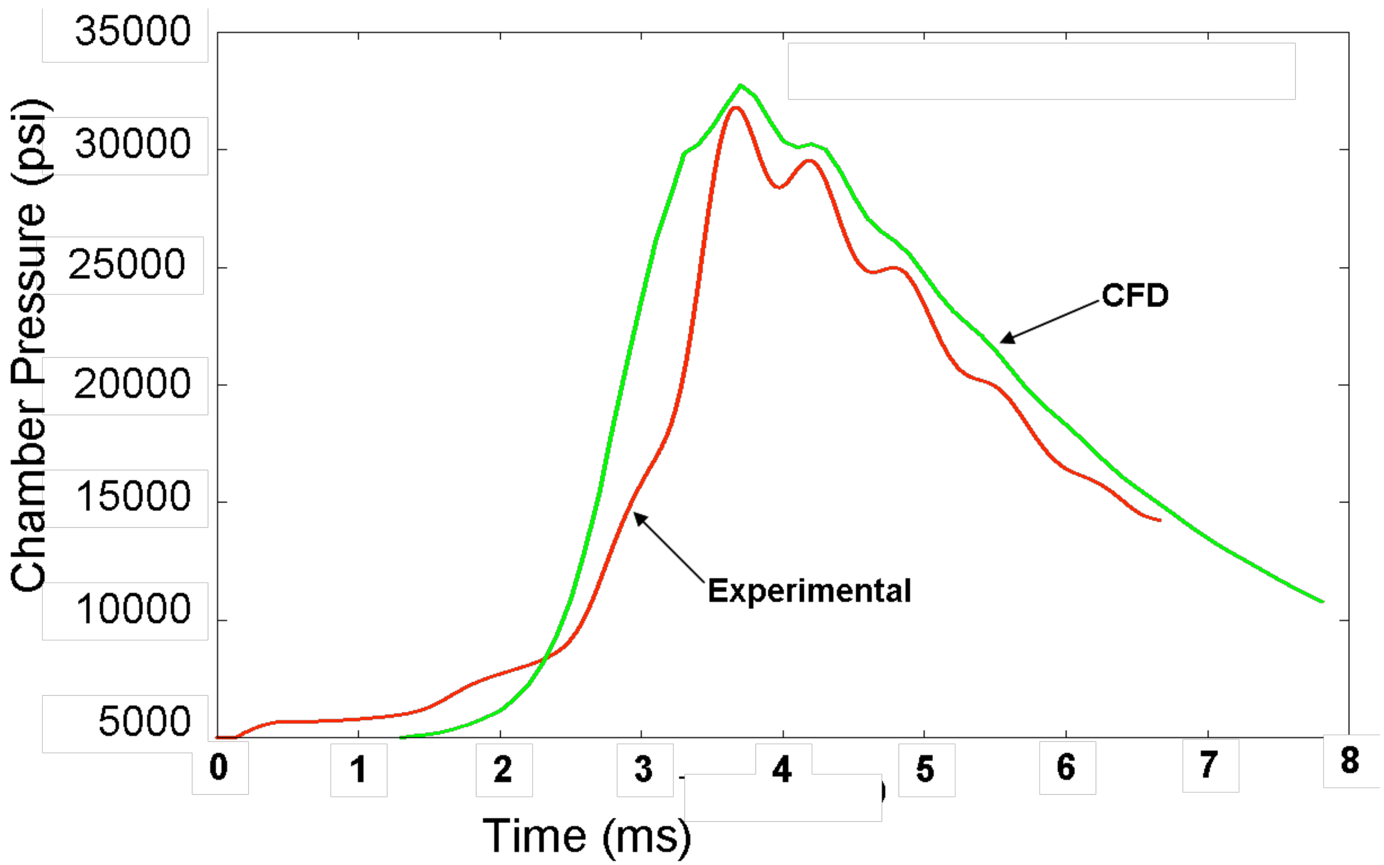
- Higher velocity
- Lower operating pressures
- Lower acceleration on projectile
- Infinite zoning
- Ability to produce propellant onsite

Combustion Control and Zoning



Modeling


34641
26321
20000
[psi]

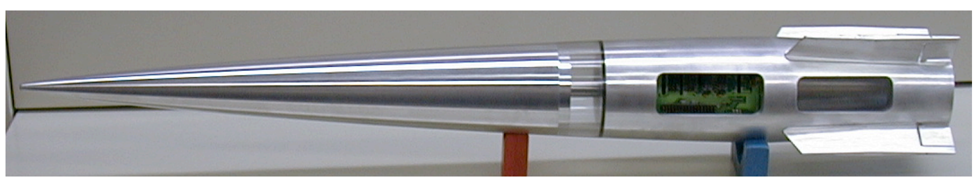

Chamber Pressure (psi)
35000
30000
25000
20000
15000
10000
5000
0
1
2
3
4
5
6
7
8
Time (ms)
CFD
Experimental

[155 mm CLGG]

14 shots with up to 28 MJ muzzle energy to date,
A fraction of its capability, tests are ongoing

155mm Test Data

Shot number	Projectile mass (kg)	Peak Chamber Pressure (psi)	Peak Acceleration (g’s)	Velocity (m/s)	Kinetic Energy (MJ)	Barrage Range (miles)
14	20.3	25,000	17,000	1667	28	111



Current Propellant Supply System

CLGG

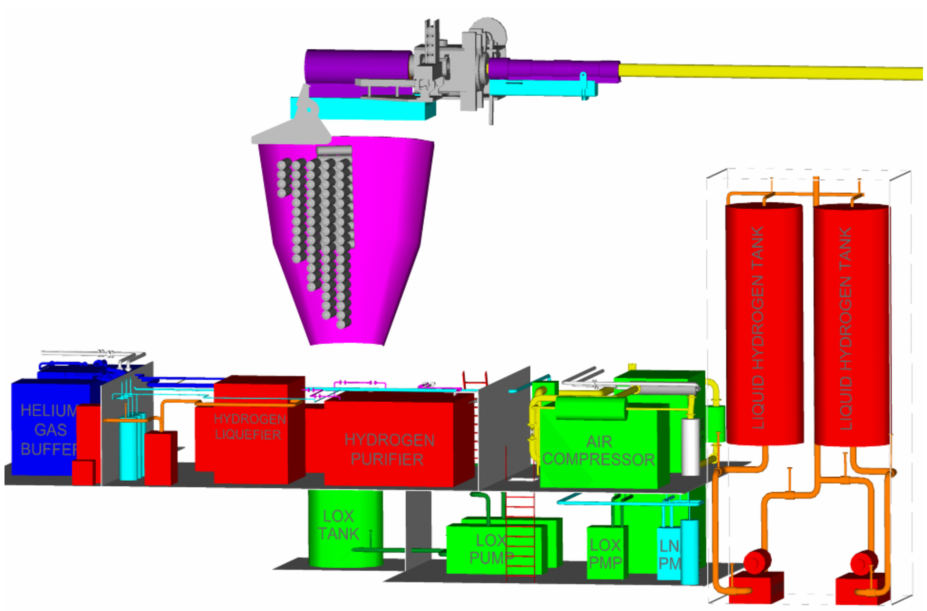
Future Propellant Production – Pilot Plant

Hydrogen Production

- Steam Natural Gas Reforming
- Diesel Reforming
- Electrolysis

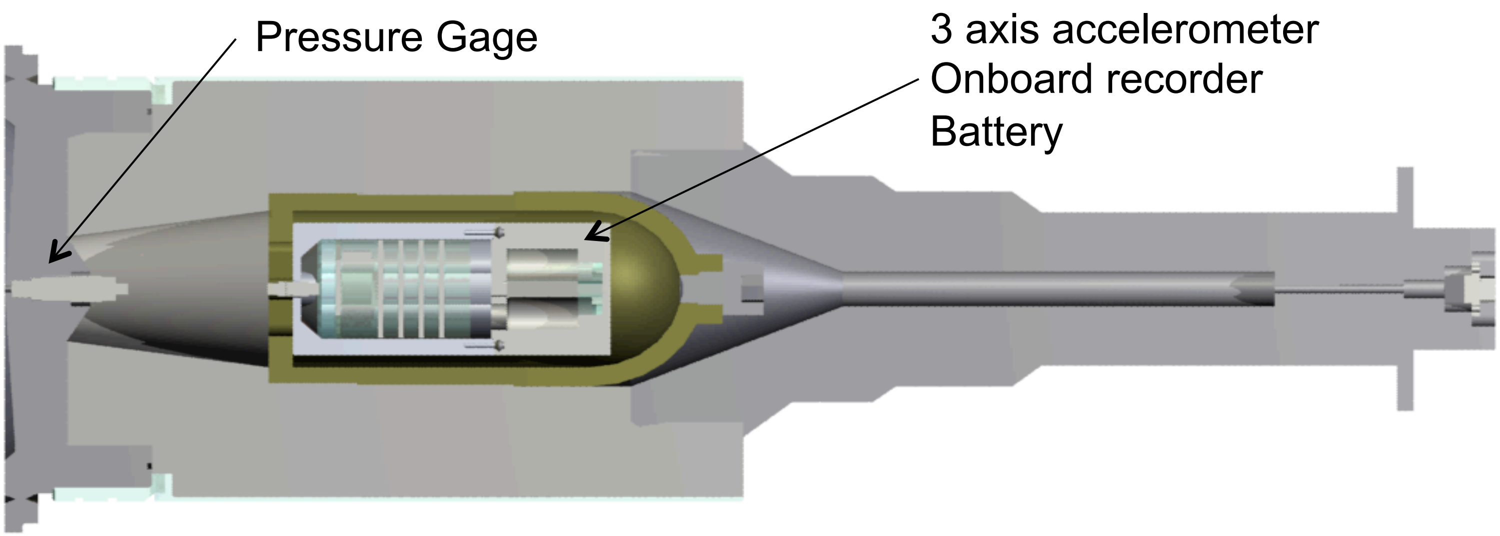
Oxygen Production

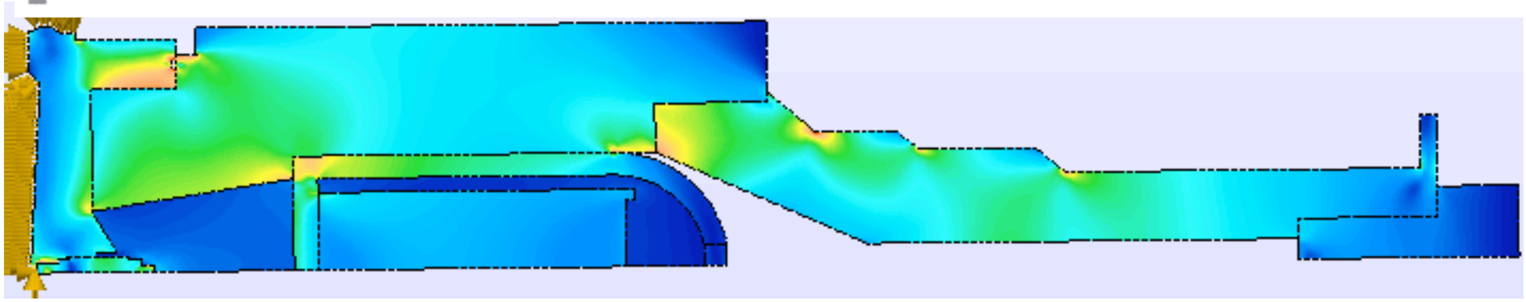
- Electrolysis
- Cryogenic Air Separation
- Pressure Swing Absorption
- Membrane Separation

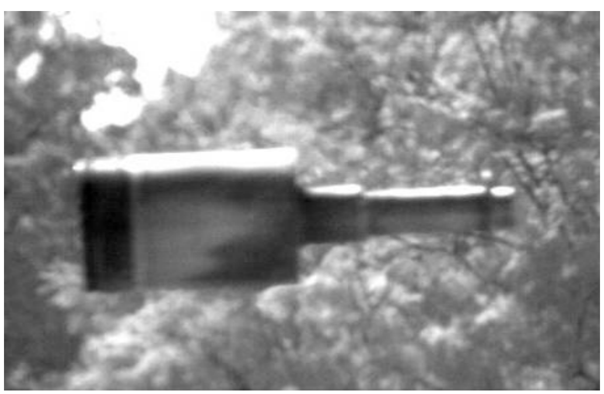


Possible pilot plant using **off the shelf** hardware

Future – Instrumented Projectiles

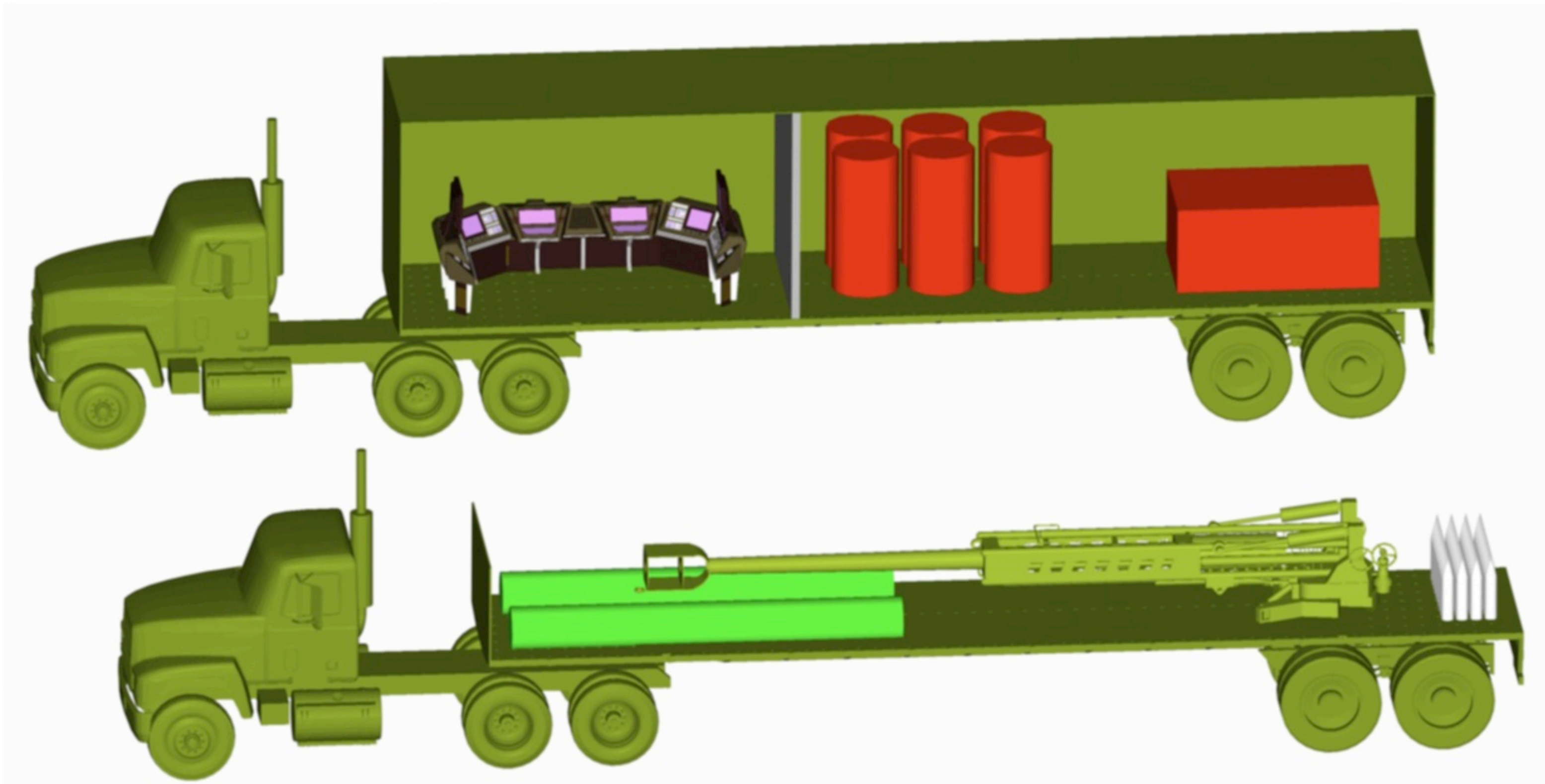






Future – Instrumented Projectiles

Future – Transportable Extreme Range System



- R&D - Support Long Range Guided Projectile Development
- Field - Provide Extreme Range Artillery Support

CLGG

CLGG

Driving Affordable Common Solutions with Mission Analysis

44th Annual NDIA Gun and Missile Systems Conference

Andrew J. Hinsdale
Sr. Engineering Fellow

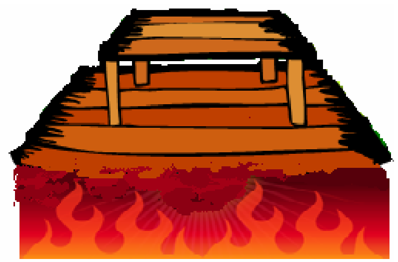
Dan F. Cheeseman
Sr. Engineering Fellow

David G. Stone
Vice President

Raytheon Missile Systems
Tucson, AZ

April 9, 2009

Burning Platform



Our customers needs are continually evolving, performance expectations grow while cost expectations drop.
To meet their needs, we must:

- Be Faster - *in development and to the field…*
  - Reduce time to concept demos
  - Reduce product development time (SDD)
- Be Cheaper – *in SDD and Life Cycle…*
  - Reduce total cost of ownership for customers
- Be Better – *continually address improved performance and…*
  - Increase the quality of our products
  - Provide extensible, adaptable, modifiable solutions to increase value to the customer

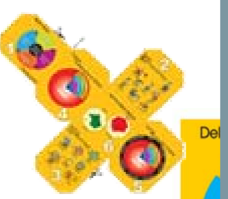
Technological innovation is only a part of the solution!

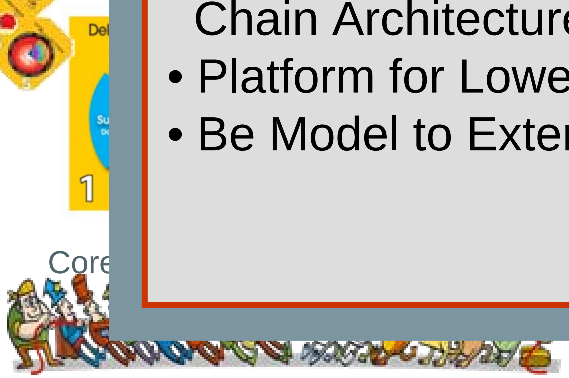
The Modularity Vision Described:
"Be Key Enabler for Design 2010 Precepts"

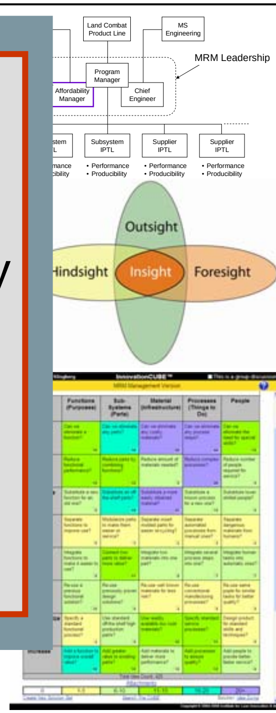
Raytheon

Understands The Use Of The Product	Makes Requirements Capability Trades Around Affordability	Determines The Manufacturing Strategy	Identifies Where To Buy From	Designs To Maximize This Strategy
Lean Innovation and Development	*Modeling and Simulation*	*Manufacturing Technology*	*Supplier Integration*	*Affordability Manager*

Workshops In
Customer and
to Define End
and Identify T
Values

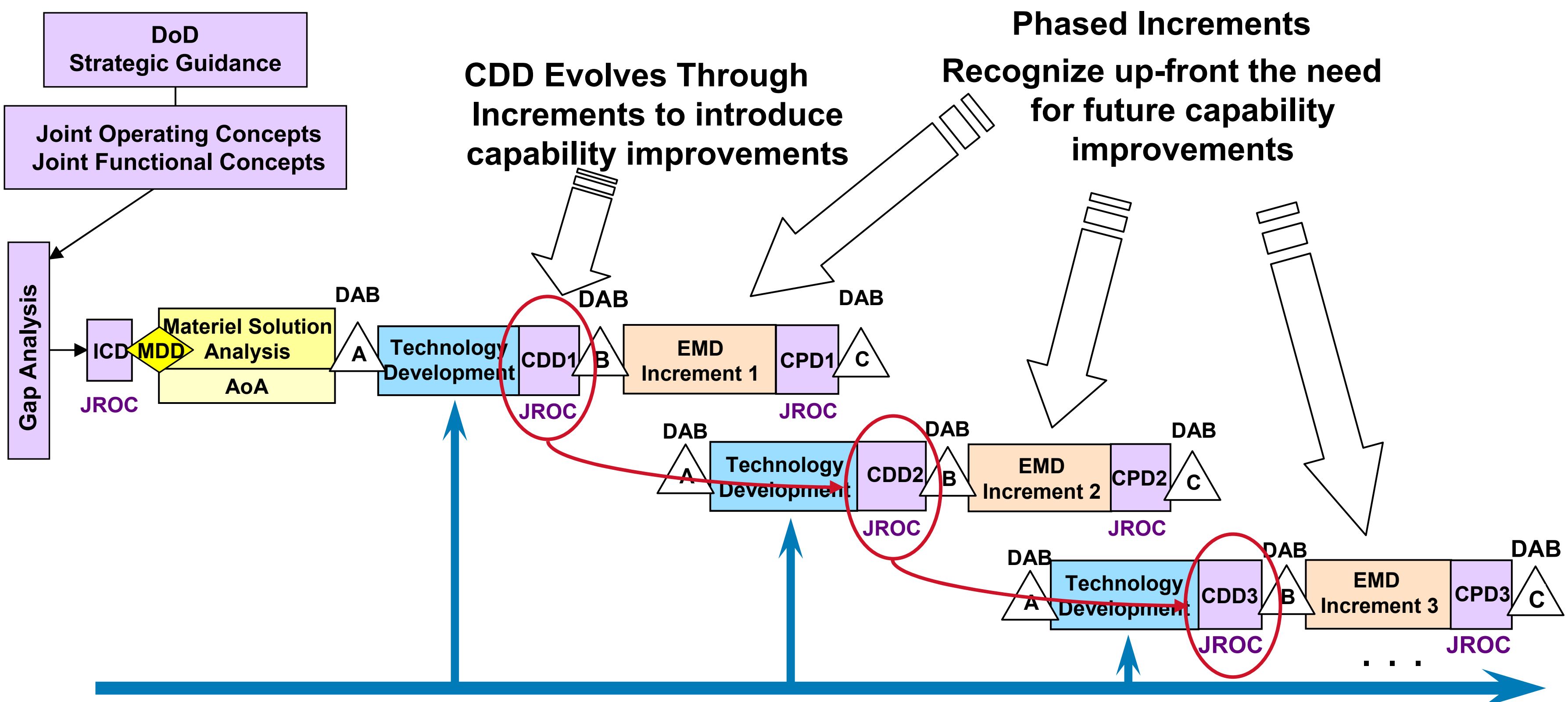






- Create Platform for Usable Design Data
- Create Platform for "Agility"
- Create Model for True Lean Design
- Show High Level Integration into the Manufacturing and Supply Chain Architecture
- Platform for Lowest Cost Design of Product
- Be Model to Extend to other products!!

Evolutionary Acquisition – DoD 5000.2

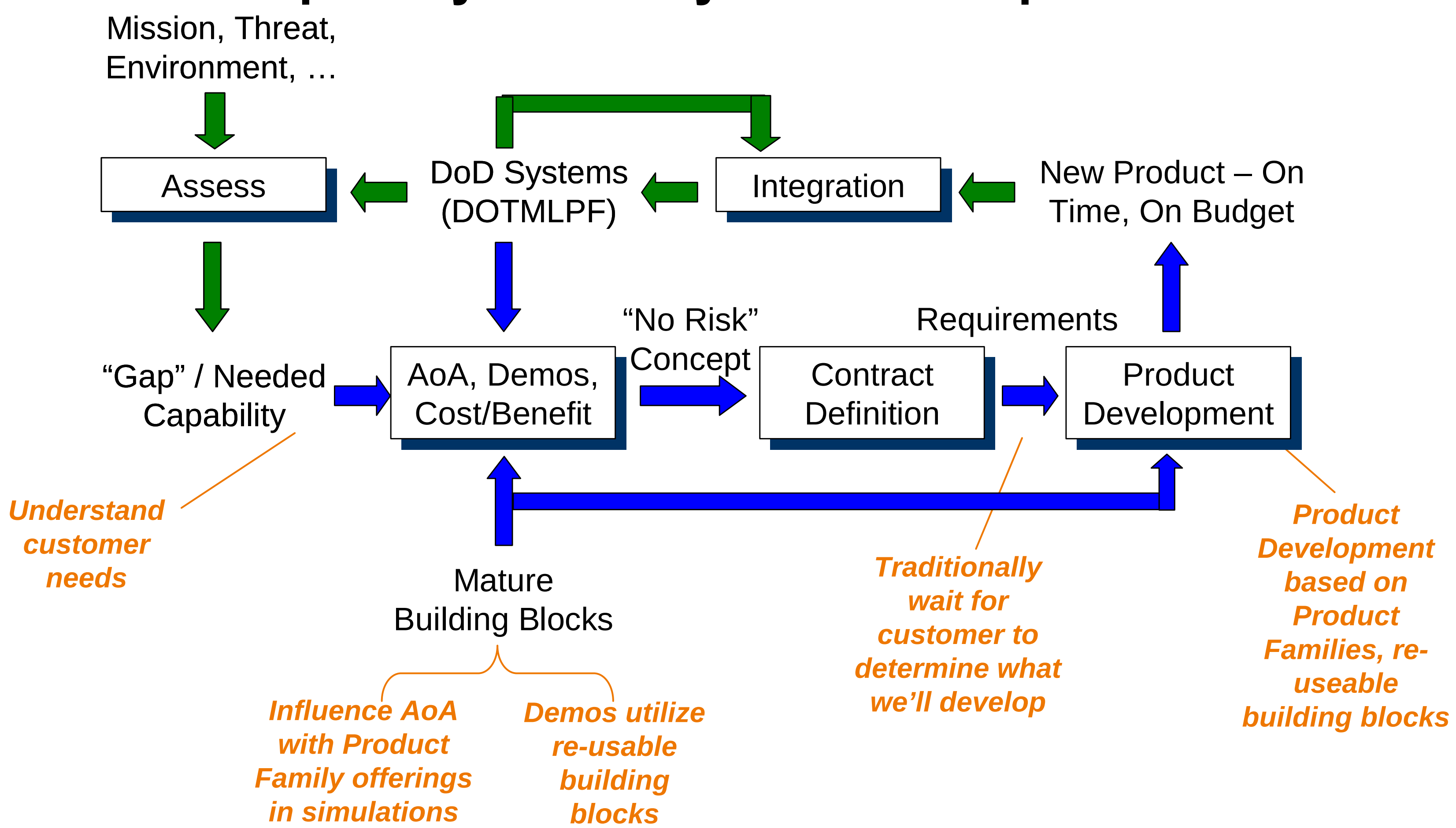


" Evolutionary acquisition is the preferred strategy for rapid acquisition of mature technology for the user."

DoD 5000.02, December 2008

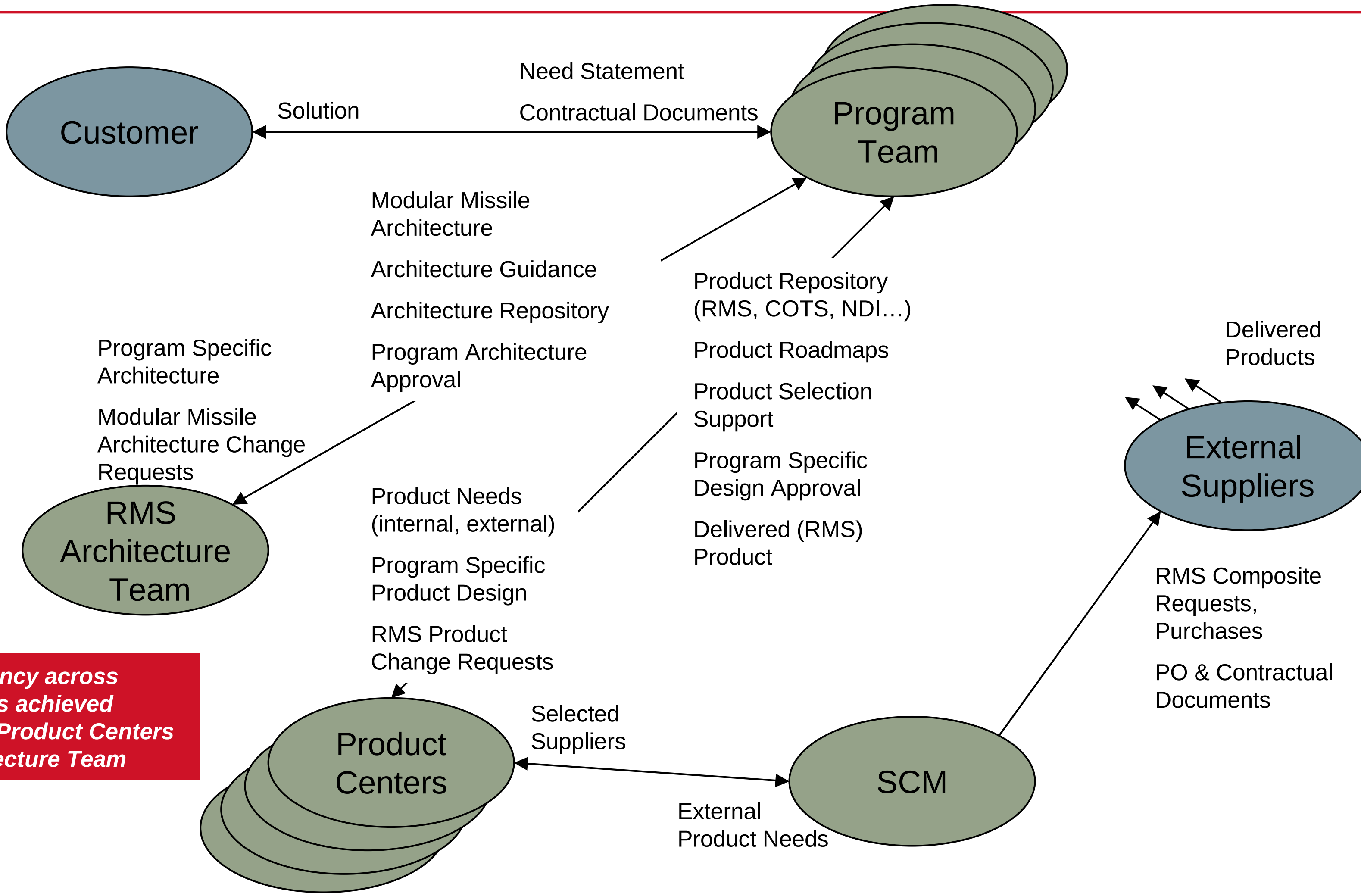
Modularity Vision Tied to Business Strategy

Capability-Based System Development



Modularity and Reuse are a comprehensive Product Strategy that support and influence the acquisition process through the use of simulations and demos

Notional Workflow – Missile Development



Consistency across Programs achieved through Product Centers & Architecture Team

Product Family Architecture and Product Center Expertise enable faster delivery of affordable, high quality customer solutions

Modularity Process and Benefits

Process	Understand What Modularity means	Generate Arch Model Reflecting Business Needs	Decompose Functional Areas	Evaluate Logical Architecture	Translate Logical Arch To Physical Architecture	Design to Standards	Repository Of Compliant Products	Assemble/ Integrate To Order
Outputs	Quality Attribute Scenarios Architectural Principles	Foundation Architecture Technical Reference Model (TRM)	Logical Architecture Functions, data descriptions	Common functions, needed variations	Physical Architecture Stds defined: Id re-usable modules, rqmts, I/O	Standard Products Development Process	Product Repository	Customer Specific Solutions

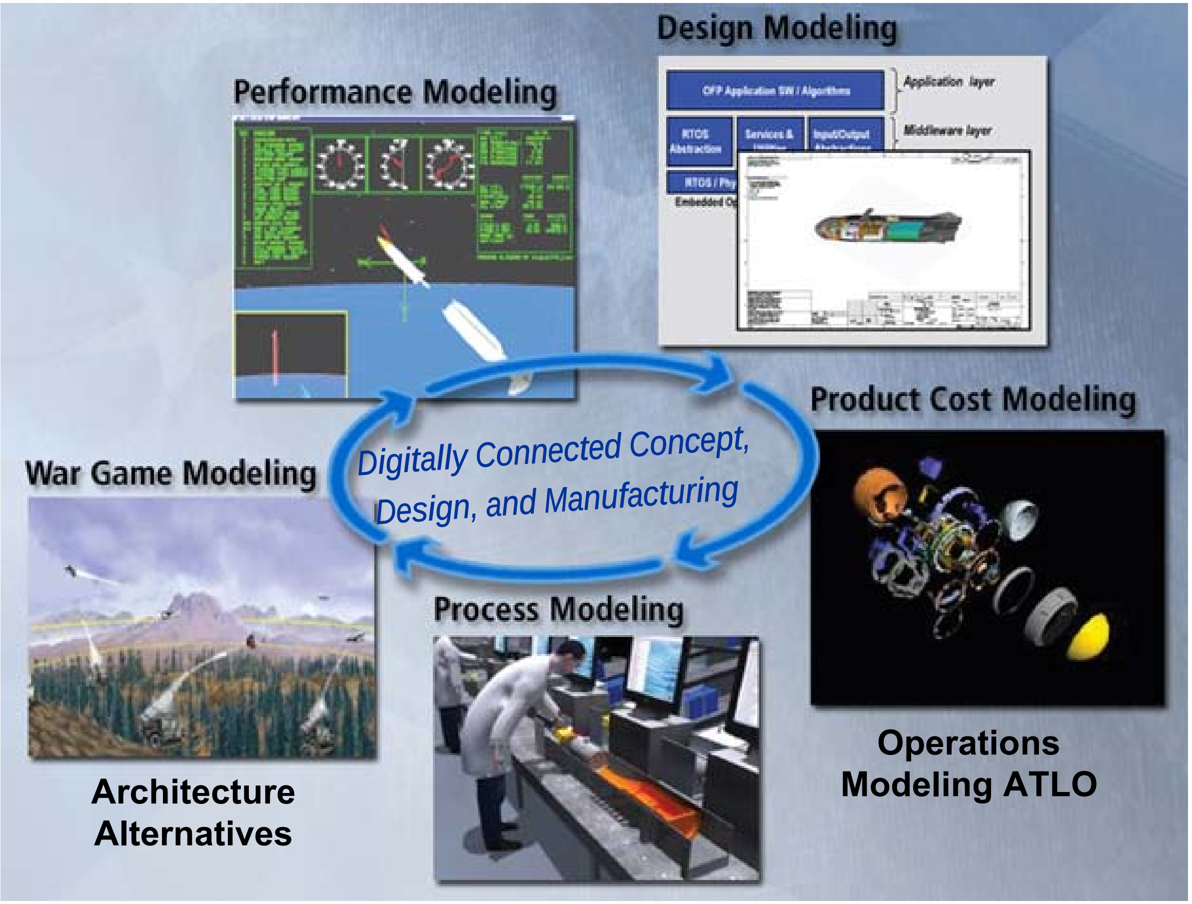
Benefits of using common architecture, reusable modules:

- Staffing flexibility- **allows staff to move easily from program to program (core set of modules and architecture looks same; only need to learn the program specific deltas)**
- Productivity increase **– low learning curve, easier to work multiple programs, learning transfers across programs**
- Predictability **– mature the modules, mature the process - enables more accurate estimates, performance prediction for people and products**
- Increased time for innovation **– reuse what's ordinary; be creative in specializing for customer, building new products from reusable product base**

Design 2010 – Changing the Paradigm

- Principles
  - Architecture Driven
    - Analysis of Alternatives
  - Model Driven
    - vs. Specification Driven
  - Rapid Prototype
    - Spiral Cycles – Virtual
    - 1st Hardware and SW
  - Lean Design Planning
    - Design Profit Day 1
  - End to End Solutions Studied
- Results (An Early Project)
  - Arch to Design Cycle 45 Days to Proto-type
  - Model-driven 6-DOF – Early
  - Design –Target Cost Model
  - Lean Design
    - Modeled/Design Profit
  - Design Cycle Improvement

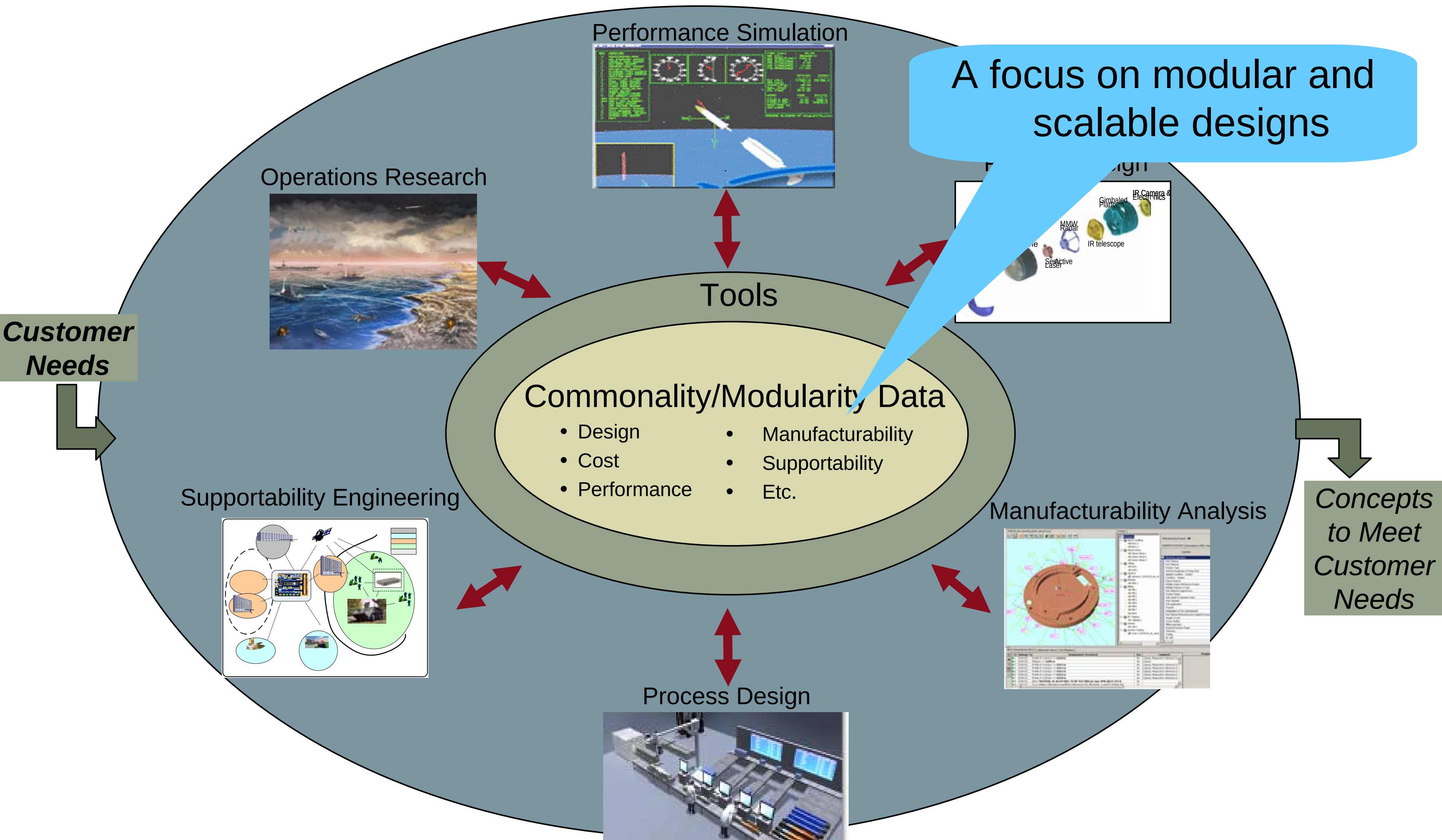
Changing The Systems Design Perspective



Design 2010 VSD - Model Driven, Robust Architecture Based Solutions

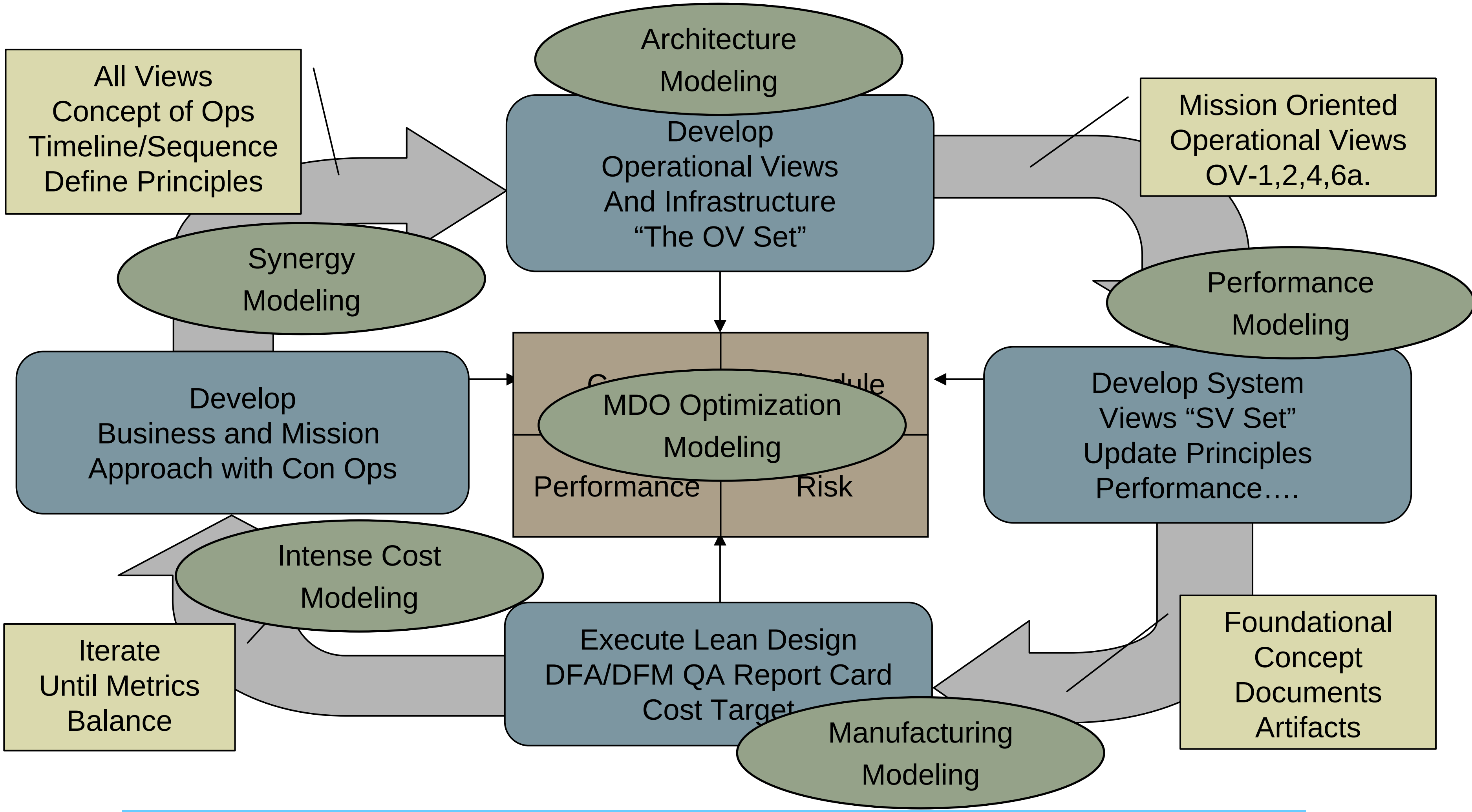
Raytheon

VSD Operational View of Architecture (OV-1)



How We Bring Architecture Together!

VSD Link
Lean Architecting to Lean Design



Foundational Approach to Lean Systems Design …
DoDAF and Zachman Methods

Raytheon

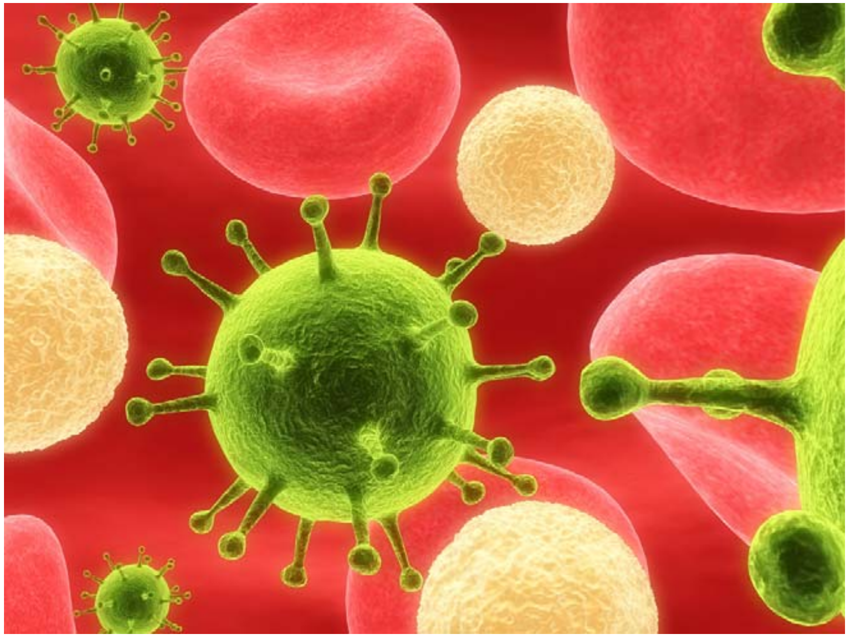
Cultural Obstacles to Lean Design and Reuse

- Engineering and production rework
- Linear Design
- Weak Systems Thinking
- Little Re-use of Previous Solutions – "Designer Preference/NIH"
- Weak "Outsight"
- Lack of Effective Collaboration
- Weak Management Support for Innovation
- Resistance to Changing Engineering Processes

Management Must Demand Design Reuse Or It Will Not Happen!

Systemic Obstacles to Lean Design and Reuse

- Defense Projects are “Cellular”
  - Designed to “stand alone”
  - Unique, inflexible specifications
  - Unique contractual requirements
  - Unique security/AT requirements
  - Difficulty in facility and capital equipment sharing
  - Inter-service differences
  - Intra-service differences
- Company & Government accounting systems geared for cellular structure



Greater Flexibility in Contracting and Specifications Development are needed to achieve higher levels of lean design and reuse

Summary

- Defense Customers are demanding that industry be *faster, cheaper, and better*
- Modularity and Reuse are key enablers for future systems
- Modularity and Reuse Benefits Everybody!
- Modularity and Reuse will not happen by themselves – it will take a concerted effort by Industry and Government

Integrating Robotic Platforms and Non-Lethals for the Future Warfighter

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Shaping the Future

Challenges

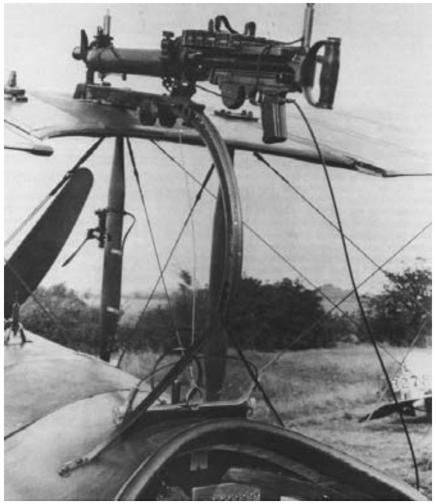
- US forces are heavily dependent on an array of major procurement programs at varying states of development
- Many futuristic systems carry multi-million dollar funding requirements extending across decades.
- The budgetary challenges and technological obstacles associated with leap-ahead concepts threaten to slow or even halt the progress.
- Cultural hurdles

Lessons From History

Every modern weapon has faced technology obstacles and cultural hurdles.

Technology

The aircraft initiated as a reconnaissance platform. Initial efforts to arm the aircraft faced many complexities



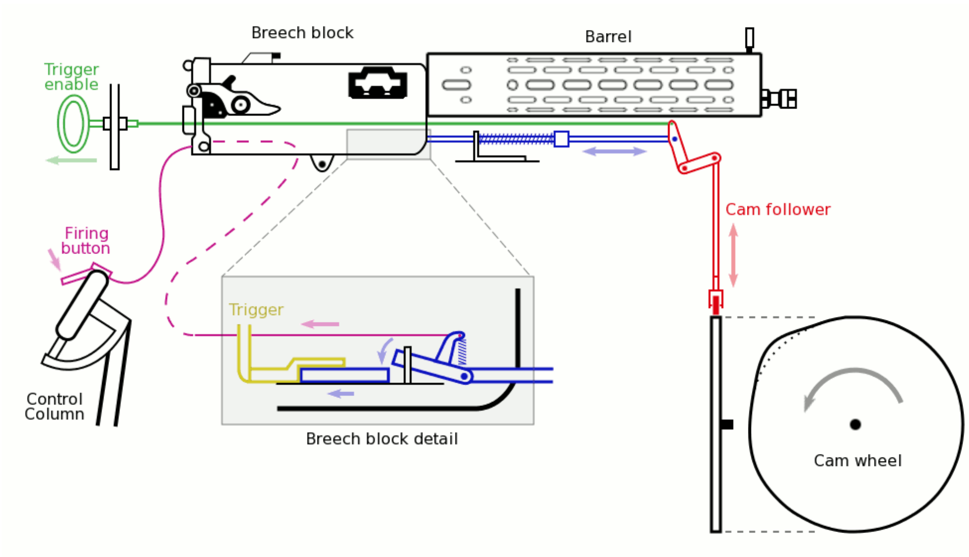
Cultural

Ferdinand Foch (*Supreme Commander of the Allied Armies*) reputedly stated in March 1913:

"Aviation is fine as sport. I even wish officers would practice the sport, as it accustoms them to risk. But, as an instrument of war, it is worthless (c'est zero)."

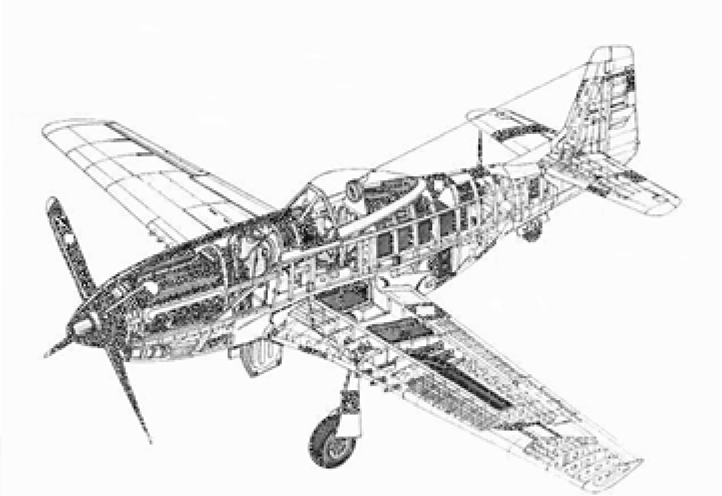
Solutions Technology

Fokker's Synchronizer



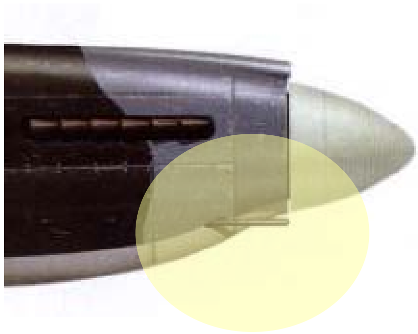
- Introduced during the First World War, the gun synchronizer was a significant development in the history of air combat and remained in operational use until the Korean War when the widespread adoption of jet aircraft rendered it obsolete.
- The synchronization gear is a triggering device attached to the machine gun armament of a early fighter aircraft so that it would fire only at certain times.
- This allows the gun to fire through the arc of a spinning propeller without the bullets striking the blades.

Evolving Capabilities



1940: North American Aviation contracted to develop the P-51 Mustang. The original NA-73X had (2) chin mounted 50 cal guns.

Within a few short years the P-51 had all wing mounted guns and began carrying rockets mounted to external wing stations.



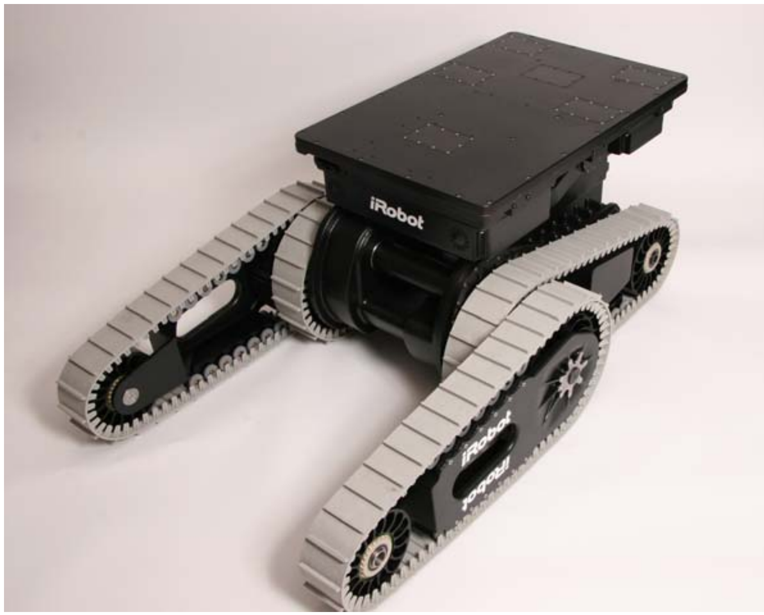
Aviation 100 Years Later

60 years later, the FA-18 exemplifies a mission and systems integration focus: The entire platform design enhances capabilities and effects for the tactical mission

The UAV community has turned the corner and adopted the concept of matching armed capabilities to mission requirements

EH GROUP INC
DEFENSE & SECURITY CONSULTANTS

Shaping Weaponization For UGVs



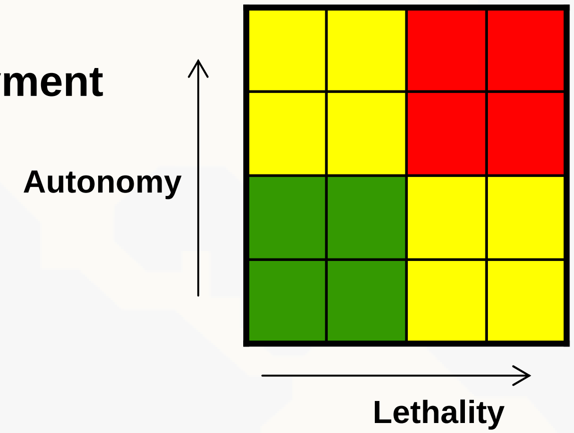
Where, when and how does the UGV community make this transition up the evolutionary ladder?

Armed Robotic Considerations

- **Operational scenarios for armed ground robotic platforms**
  - **Room Clearing**
  - **Crowd Control**
  - **Perimeter Patrol**
  - **Route Reconnaissance**
  - **Convoy Security**
  - **Border Security**

- **State of the art enabling technologies and their maturity level**
  - **Weapons suites designed for the robotic platform**
  - **Sensor integration that brings situational awareness levels close to human capacity**
  - **Size, weight transportability**
  - **Power**

- **Cultural/legal/policy issues that may limit employment of armed robotic systems**
  - **Tradeoffs in assured control**



Armed Robotic Platforms

iRobot's Warrior X700 with
Metal Storm's FireStorm
Non-Lethal Weapon Payload

Length:	**35 inches**
Width:	**29 - 32.5 inches**
Chassis Weight:	**~300 lbs.**
Payload:	**125 lbs**

Shaping the Road Ahead

Measured Steps to Shape the Armed Robot

- Face the cultural abyss
  - Acknowledge that there is a future for armed robotics
  - Don’t just leave this up to the robotics community
- Field solutions to explore TTPs and develop doctrine
  - Experimentation
- Fund weapons projects
  - Projects that require a broad expanse of industry cooperation
    - Platforms
    - Sensors
    - Payloads
    - Munitions
- Focus

Future Capabilities

ECL® Propellant Demonstration

Consolidation of 105 mm Artillery M67/M200

into Single Charge System

Benefits for the Warfigther

Kelly Moran (ATK)

Nguyen Tran (ARDEC)

Dominik Antenen, Peter Zoss, Kurt Ryf (Nitrochemie)

NDIA Conference

44th Annual Gun & Missile System Conference

Kansas City, 8th April 2009

Main Goals of Improvement Program

- Replace current charge system M67 (7 zones) and M200 (standalone long range)
- Create compact charge system with 5 – 6 zones with sufficient overlap capacity
- Facilitate handling for operation, improve reliability and shelf live for operation in complex terrain under extreme loads
- Optimize life cycle cost

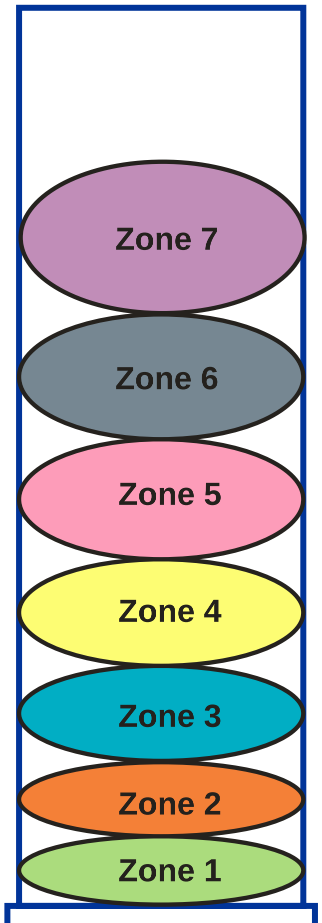
Current Situation – M67 and M200

Gun
- M119A2

Propellant
- M1 (DNT, DBP, DPA)

Range
- 11,5 km

M 67



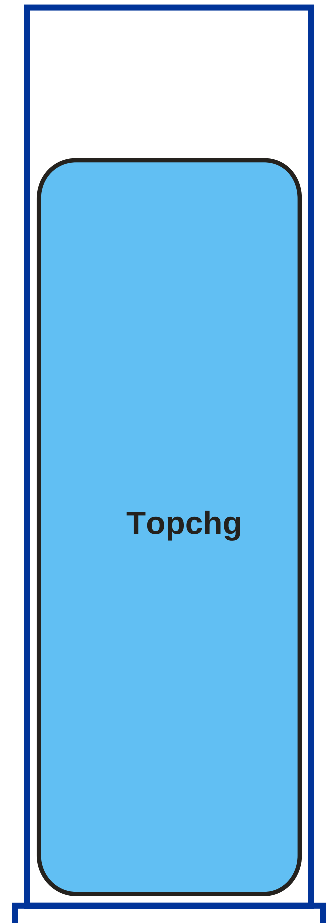
Goal

Logistic advantage

Higher stow capacity

Lower overall cost

M 200



Gun
- M119A2

Propellant
- M30 (NG, NQN)

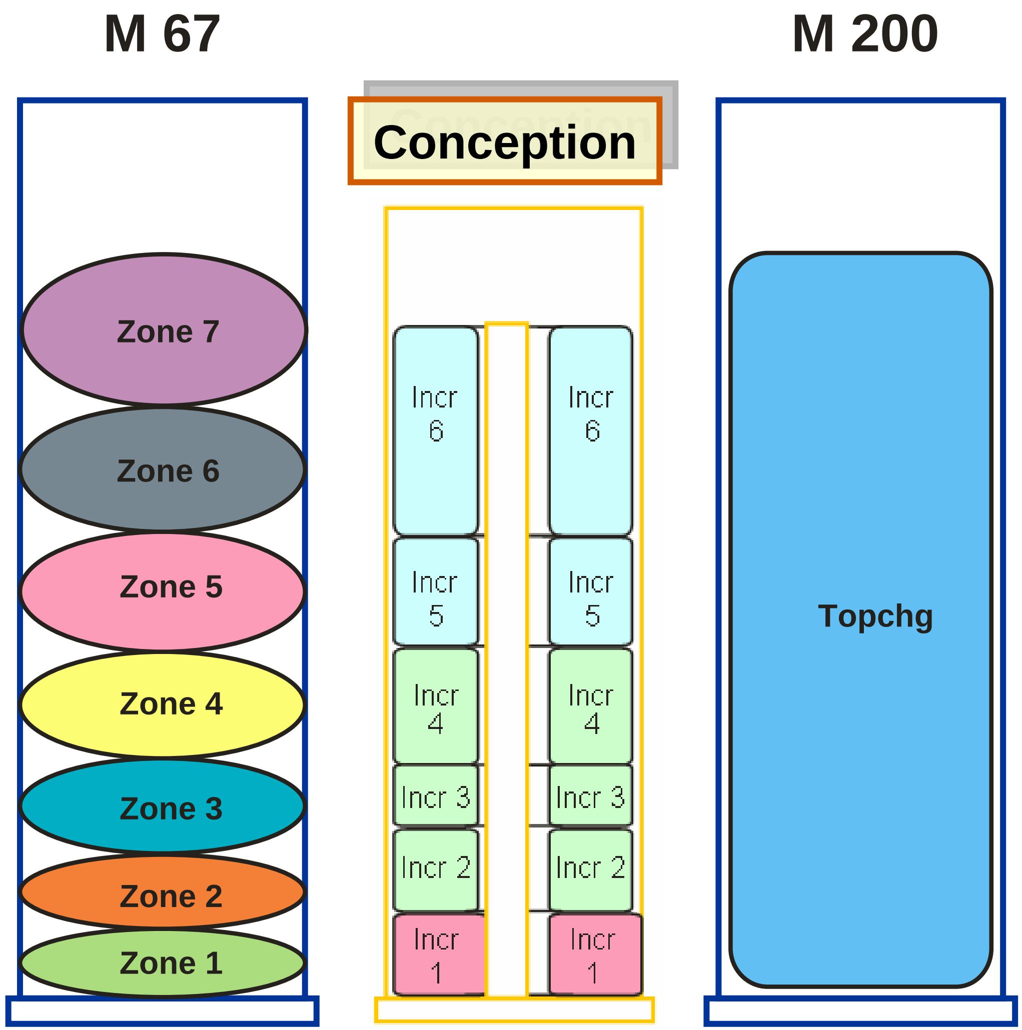
Range
- 14 km

Single Charge System with 6 Zones

Gun
- M119A2

Propellant
- M1
  (DNT, DBP, DPA)

Range
- 11,5 km



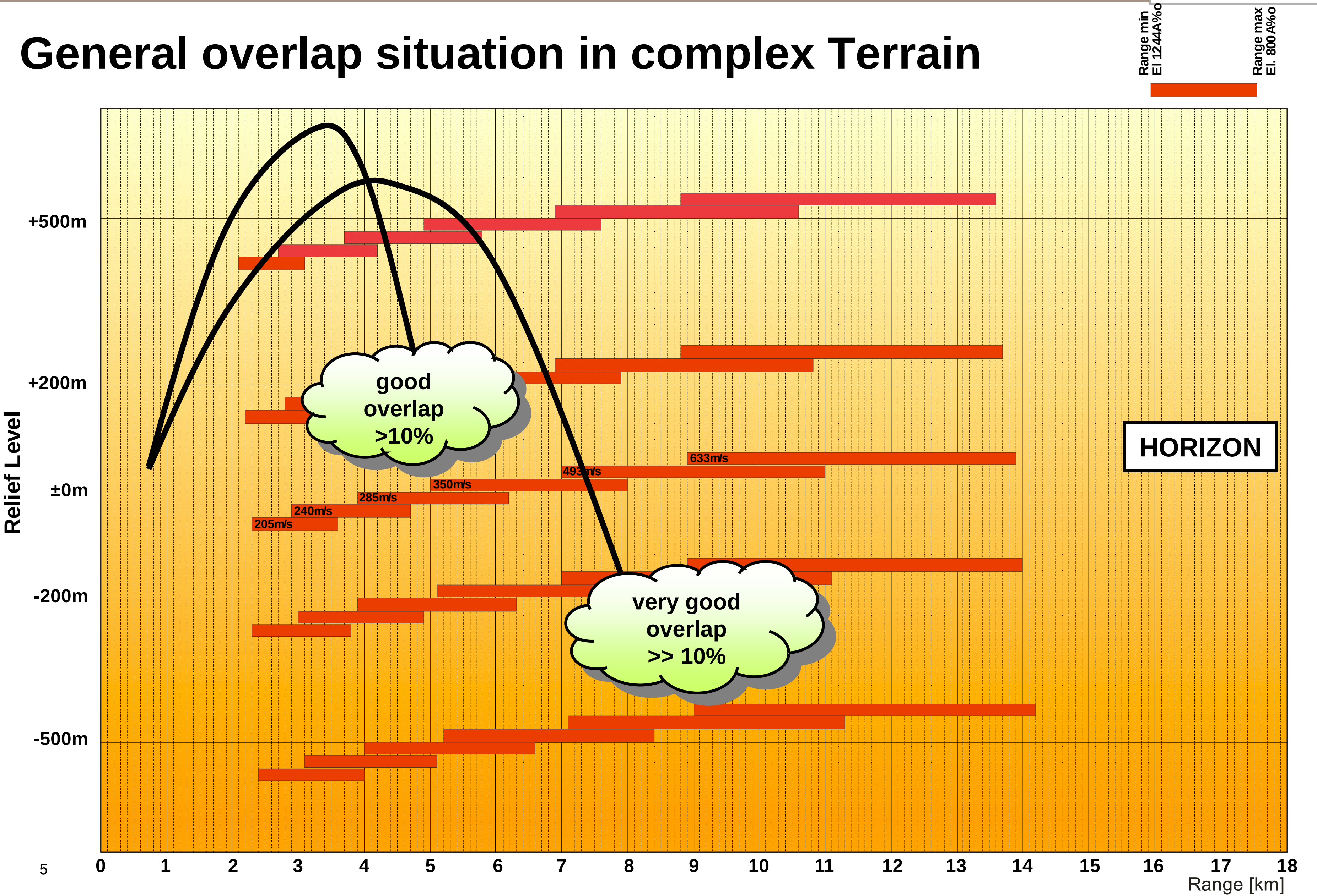
Gun
- M119A2

Propellant
- M30
  (NG, NQN)

Range
- 14 km

Nitrochemie's Proposed 6 Zone Design Solution

General overlap situation in complex Terrain



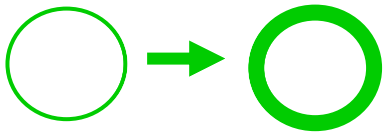
ECL® - Advanced Charge System Concept

General Benefits over *NG containing Propellants*

Chemical Compatibility
- → bag materials
- → igniter materials
- → varnishes

No Migration of NG
- → safety
- → igniter
- → bags, containers

Shelf Life and IM Properties
= essential for freedom missions!



Improved IM Properties
- → external mechanical impacts
- → cook-off resistance

No Diffusion of Deterrents
- → consistency in ballistic performance
- → no detoriation of accuracy

Improvement of Charge Compactness

Donut Bags Improve Loading and Handling of Propellant Charges

Current bag design (M67 and M200)

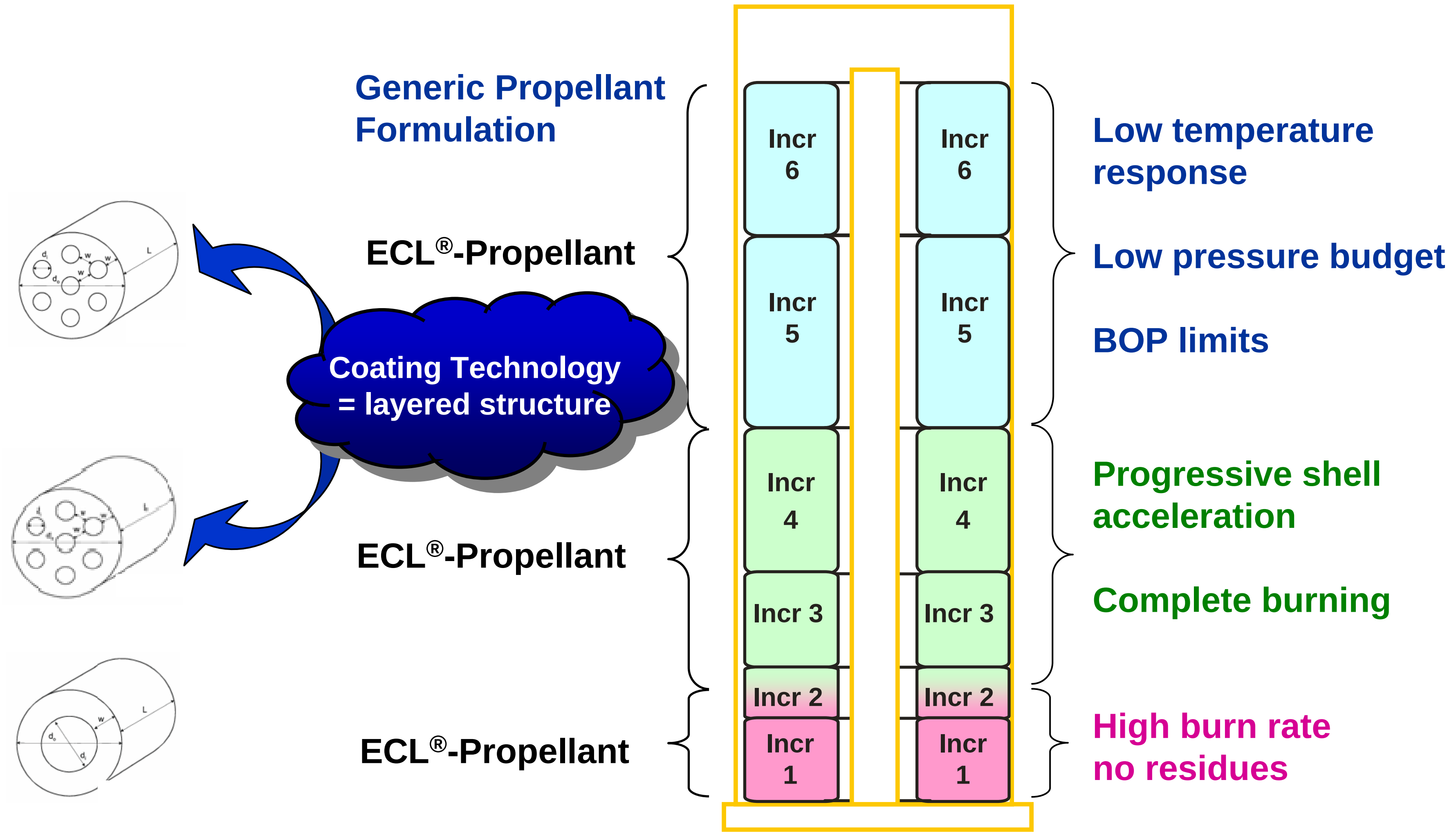
poor loading capacity of M67

Proposed design for single integrated charge system (XM350) includes donut-style bags of 3 different sizes providing:

- ***optimal loading capacity!***
- ***easy handling for troops***

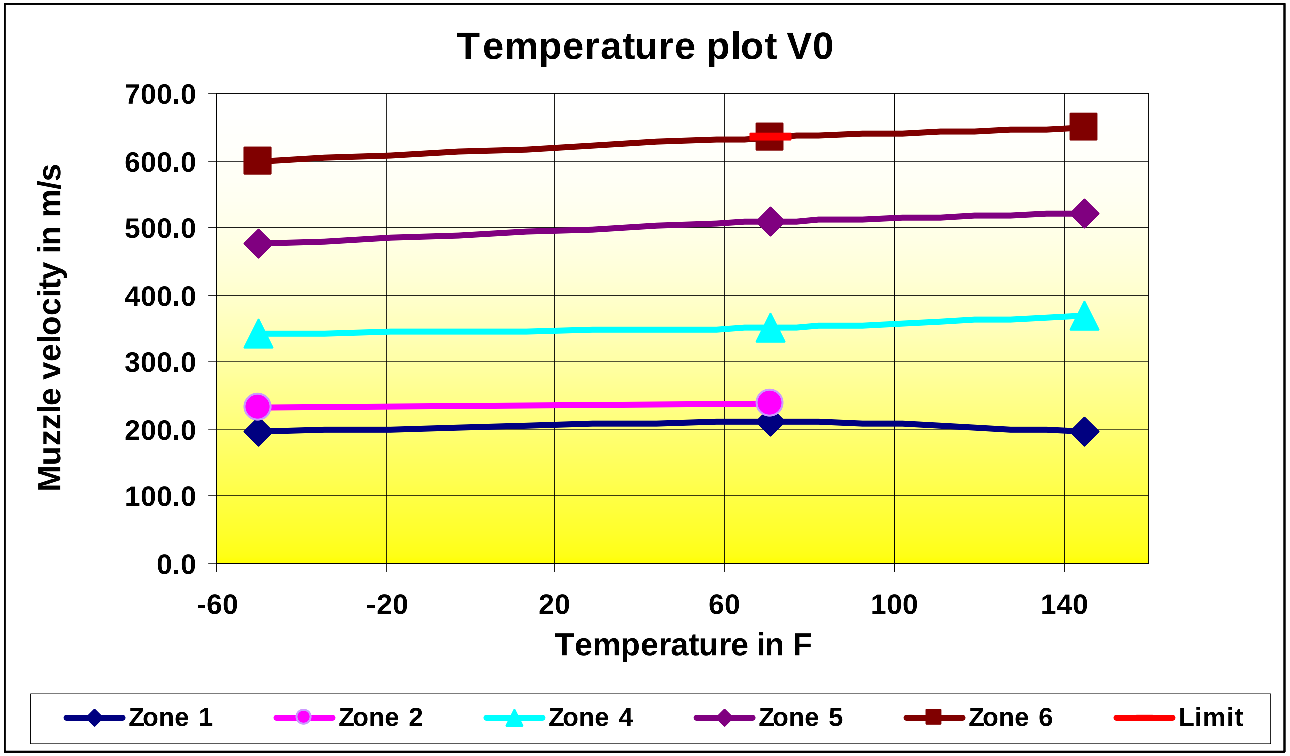
The Propellant Charge Combination

Tailored ECL® Propellant Design for 6 Zone Concept



Demonstration Firing (Yuma June 2008)

Results of Velocity Measurements



Goals @ 70F

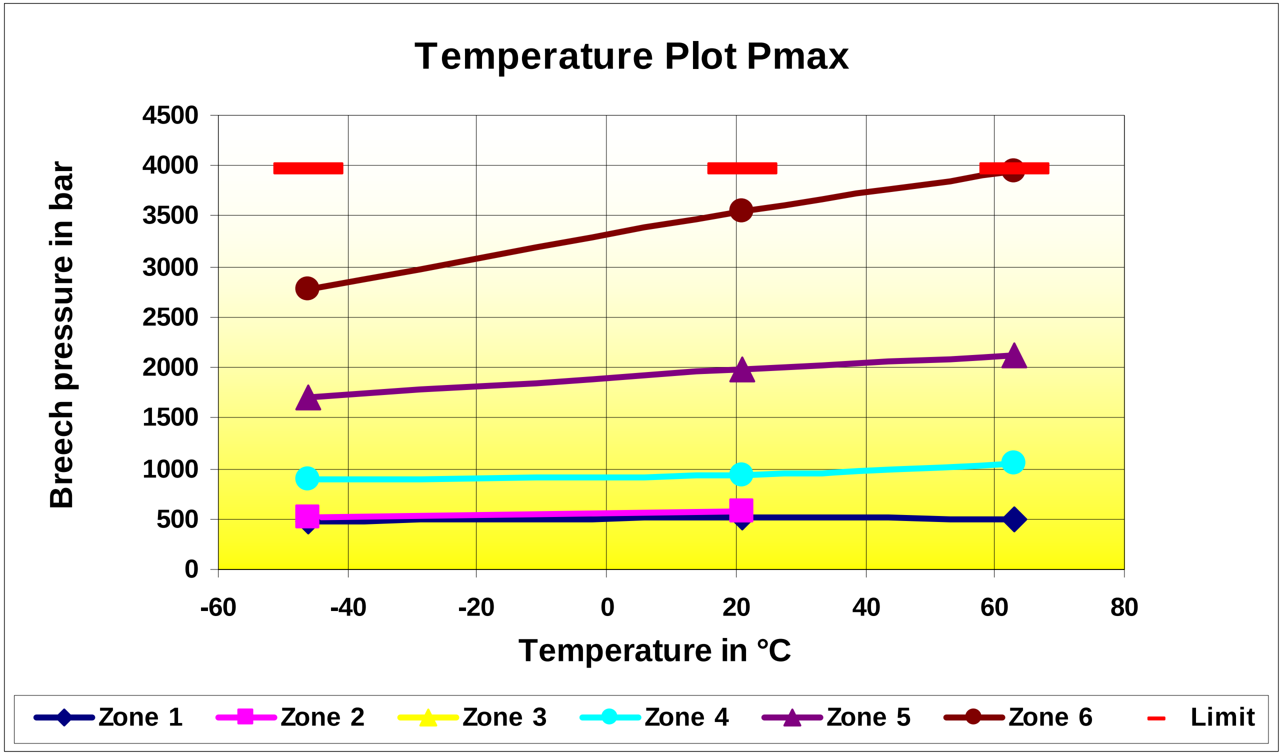
Zone 1	199m/s
Zone 2	238m/s
Zone 3	285m/s
Zone 4	350m/s
Zone 5	501m/s
Zone 6	652m/s
Zone 6 nominal (MIL)	633m/s

Achieved: 634.5m/s @ Zone 6 and +21°C
Not fired: Intermediate Zone 3

Velocities close to targeted ranges

Demonstration Firing (Yuma June 2008)

Results of Pressure Measurements (Piezo)



Pressure limit

57500psi

3965bar

Pressure requirements achievable by correction of propellant design (known and reliable measures)

Pressure at hot close to permissible limit!

- **Correction of temperature response for high zone!**
- **Modelling of propellant design (coating parameters)**
- **Optimization of pressure budget (headroom in charge weight)**

Demonstration Firing (Yuma June 2008)

ATK
RHEINMETALL NITROCHEMIE

Summary and Conclusions

- **6 Zone conception with propellant design based on same generic formulation (3 different grain types of ECL®)**
- **Required and targeted velocities for individual charge increments fulfilled**
  → Range and overlap requirements
- **Pressure budget for highest zone at hot (145°F) close to operational pressure limit**
  → Temperature response of higher charge zones to optimize (adaptation of burn rate profile)
- **Consistent pressure – time curves (no signs of pressure waves = safe for firing at any condition)**
- **Headroom for propellant charge for optimization of pressure budget**

Final Requirement achievable with slight modifications!

Two Major Influences on Barrel Wear

- Barrel wear due to Thermal Erosion
- Barrel wear due to Chemical Erosion

Comparison ECL Charge Design vs fielded Design (results from YPG firing test June 2008)

M67 Zone 7

M1 propellant (flame temperature 2575K)

- Velocity 503.3m/s

- Pressure 39275psi

M200 (stand alone charge)

M30 propellant (flame temperature 3070K)

- Velocity 651.5m/s

- Pressure 46081psi

ECL (Zones 5 and 6)

ECL propellant (flame temperature 2850K)

- Velocity zone 5 509.6m/s

- Velocity zone 6 634.5m/s

- Pressure zone 5 28698psi

- Pressure zone 6 50812psi

Calculation of Erosion (thermo-mechanical approach)

$$\text{Erosion} \sim (m_c)^{1.5} \cdot (T_{ex})^{7} \cdot (v_0)^{1.4} \cdot (p_{max})^{5}$$

Semi-empirical formula based on experience and measured values

m_c	=	Charge Mass
Tex	=	Flame Temperature
v_0	=	Muzzle Velocity
p_{max}	=	Peak Pressure

Barrel erosion has been measured through life assessment and proof in tank and artillery guns.

Measurements in plain steel barrels with mechanical measurement and thin layer method (activated steel).

Theoretical Assessments to Barrel Erosion

Barrel Life Estimation Assessments (Different comparisons)

$$\text{Erosion} \sim (m_c)^{1.5} \cdot (T_{ex})^{7} \cdot (v_0)^{1.4} \cdot (p_{max})^{5}$$

Semi-empirical formula shows the main drivers for barrel erosion are flame temperature and pressure level

M200 vs ECL zone 6
Theoretical; only flame temperature changes — **- 41% less erosion**

M200 vs ECL zone 6
Practical; ECL not optimized; YPG results — **- 7% less erosion**

M67 zone 7 vs ECL zone 5
Practical; ECL not optimized; YPG results — **- 62% less erosion**

M200 still slightly more erosive compared to ECL® Zone 6!

M67 Zone 7 significantly more erosive compared to ECL® Zone 5!

Calculation of erosion (thermo-chemical approach: Lawton)

Erosion = A exp (Tmax / Bo)

Theoretical approach with respecting gas composition

- A: Propellant erosion coefficient (depends on propellant gas composition)
- Bo: Hardness coefficient (105 for typical gun steel)
- T_{max}: Maximum bore temperature during firing (assumption 80% of flame temperature)

- $A = \exp(0.23f(CO_2) + 0.27f(CO) + 0.28f(H_2O) + 0.74f(H_2) + 0.16f(N_2) + 1.55f(R) - 31.36)$

- f: The volume fraction of each species in percent
- f(R): Represents the dissociated products

Hydrogen as main cause for erosion (steel attack)

Conclusions

- Thermal Erosion and Chemical Erosion have different aspects which have to be observed separately!
- Erosion calculated by thermo-mechanical approach shows good-natured behaviour of ECL propellant!
- Erosion compared to M67 charge (M1 propellant) expected to be significantly lower (pressure difference)
- Erosion compared to M30 (stand alone charge) at least comparable or slightly better for ECL propellant (lower flame temperature)!
- The thermo-chemical approach by Lawton results in comparable erosion due to comparable Hydrogen contents (for same pressure)!

Theoretical and Practical Simulation

Modelling of Propellant Design

Methodology for Simulation of Ballistic Data

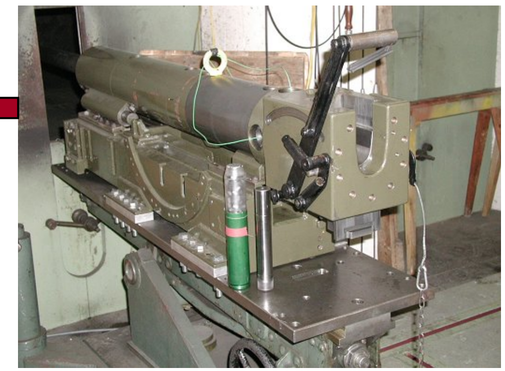
Thermodynamic Data
- Code

Burn Rate Date
- Closed vessel
- Pressure-time history

Simulation of closed vessel
- Burn Rate Coefficient
- Coating Effects

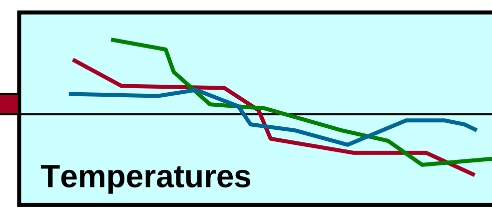
IB - Code
- System data
- Prediction of ballistic performance data

Gun Simulation
- 38mm firing tests



Data Analysis
- Gun system → simulation

Result
- Correlation factors for V / P



Δ

Correlation
- Model Adaptation

Reliable prediction
- ***Propellant design modelling***

Follow-on Work

Adaptation of Propellant Design

Analysis of firing results (2009)

Reproduction in larger quantities

US Qualification ?

Acknowledgments

- ARDEC for supporting ECL technology for this program
- Nguyen Tran from ARDEC for leading this project
- Peter Zoss and Kurt Ryf from Nitrochemie as co-workers from Nitrochemie
- Kelly Moran, Duncan Langlois and Steven Ritchie from ATK as our strategic partner

Point of contact: kurt.ryf@nitrochemie.com

THANKS!

A premier aerospace and defense company

44th Annual Gun & Missile Systems Conference & Exhibition
Kansas City, Missouri
9 April 2009

PGK Precision Guidance Kit
Affordable Precision for Future Artillery

Doug Storsved

Chief Systems Engineer
ATK Advanced Weapons

Approved for Public Release, POA 29-09, dated 24 Oct 2008,22 CFR 125.4(b)(13) applicable





Types of Precision Munitions

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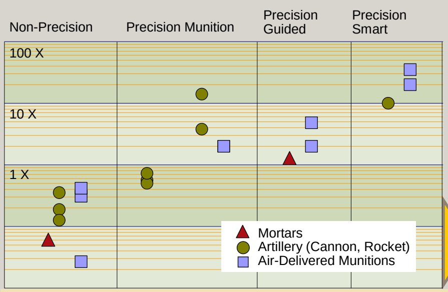
Current Paradigm:

Order of magnitude cost increase from:

- Unguided to Precision
- Precision to Autonomous



Non-Precision (Area) Munition	Precision Munition Kits	Precision Guided Munition	Precision Smart Munition
Munition/submunitions subject to all ballistic conditions on the way to the AIMPOINT.	Munition corrects for ballistic conditions using guidance and control up to the AIMPOINT	Munition guides to TARGET with <10m accuracy delivering unitary or submunition warhead. Submunitions are subject to ballistic conditions to the AIMPOINT.	Munition/submunition autonomously searches, detects, classifies, selects, and engages TARGET(s). Has a limited target discrimination capability.

Relative Cost

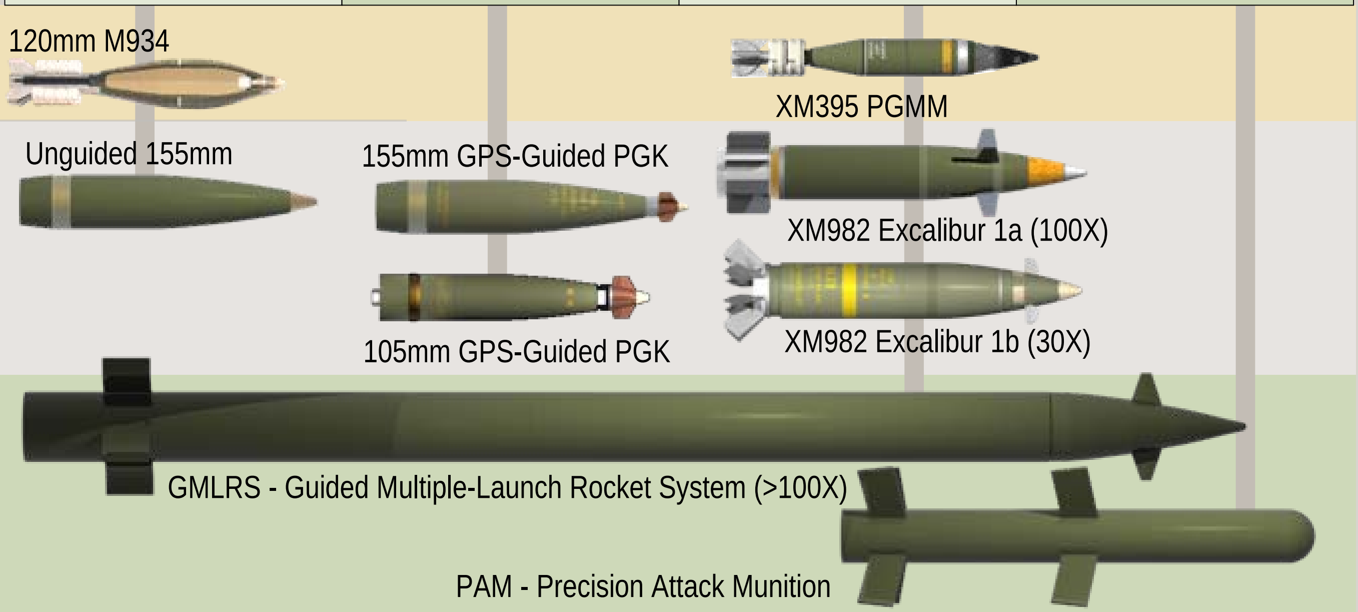
1X	3-5X	~10-100X	~100X

120mm Mortar Ammunition

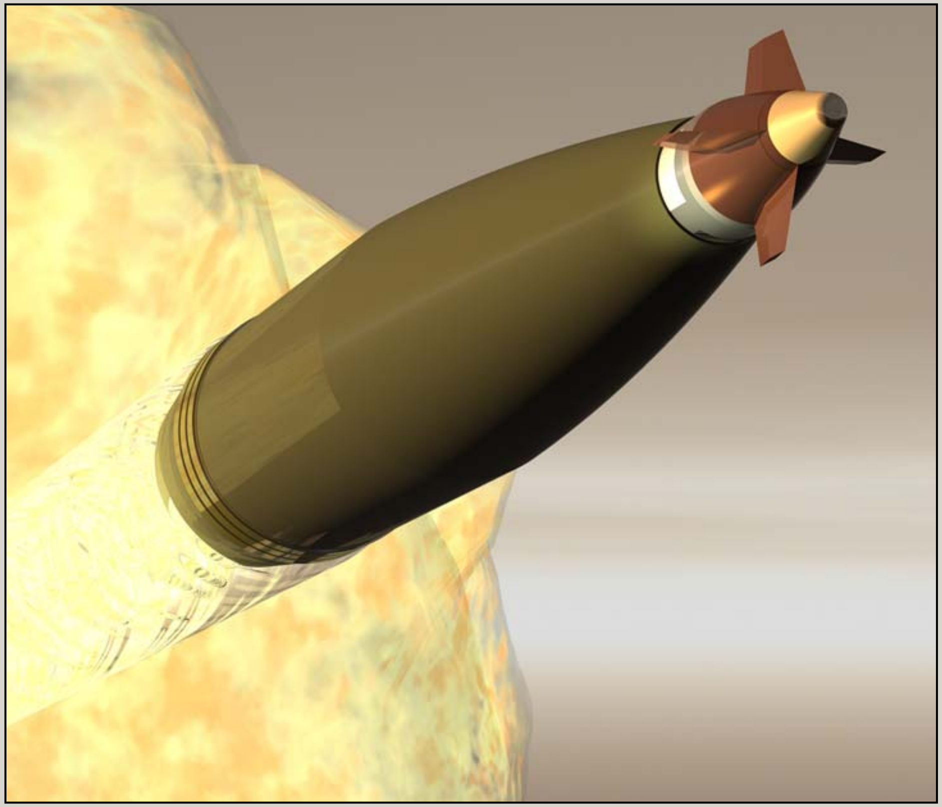
105mm/155mm Cannon Fired Artillery Ammunition

221mm Rocket-Launch Artillery Ammunition

178mm Rocket-Launch Artillery Ammunition



Precision Guidance Kit (PGK)



Operational Benefits

- Transforms existing artillery inventory into affordable precision weapons
- Improves combat effectiveness
- Reduces collateral damage
- Reduces logistics footprint

What is PGK?

- GPS Guidance Kit with Fuzing Functions
- Replaces the standard 155mm artillery projectile fuze
- PGK GPS guidance greatly improves the accuracy of conventional artillery in the inventory

  <50m CEP vs. >200m CEP at max range

- Maintains >90% of range capability of conventional projectile
- Requires no battery
- Has no “one-shots” or canard deployments
- Reliable - one moving “part”
- Uses COTS inertial sensors
- Full 2D Guidance to Impact

PGK Field Testing

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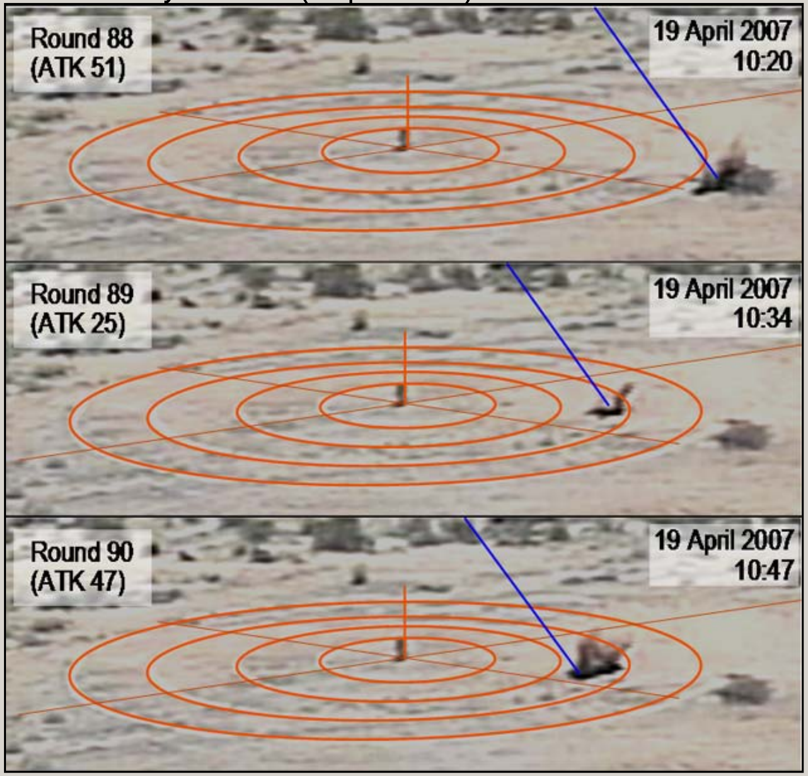
Technical Demonstration Program

Competitive Fly-Off
18 M549A1 Rounds @ 20.5 km
Demonstrated < 50m CEP
83% Reliability

2D Guidance Has Potential
To Be Very Precise (Repeatable)



Early SDD Field Test Objectives:

- Expand Aerodynamic and Guidance Characterization of PGK across family of 155mm Projectiles
- Validate Consolidation and Packaging to SDD-1 Electronics Form Factor
- Confirm System Performance of Second Source GPS Supplier

Non-Precision Conventional Mission

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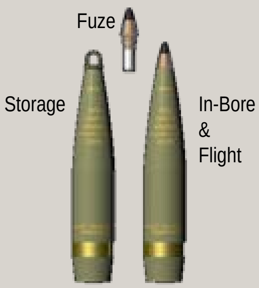

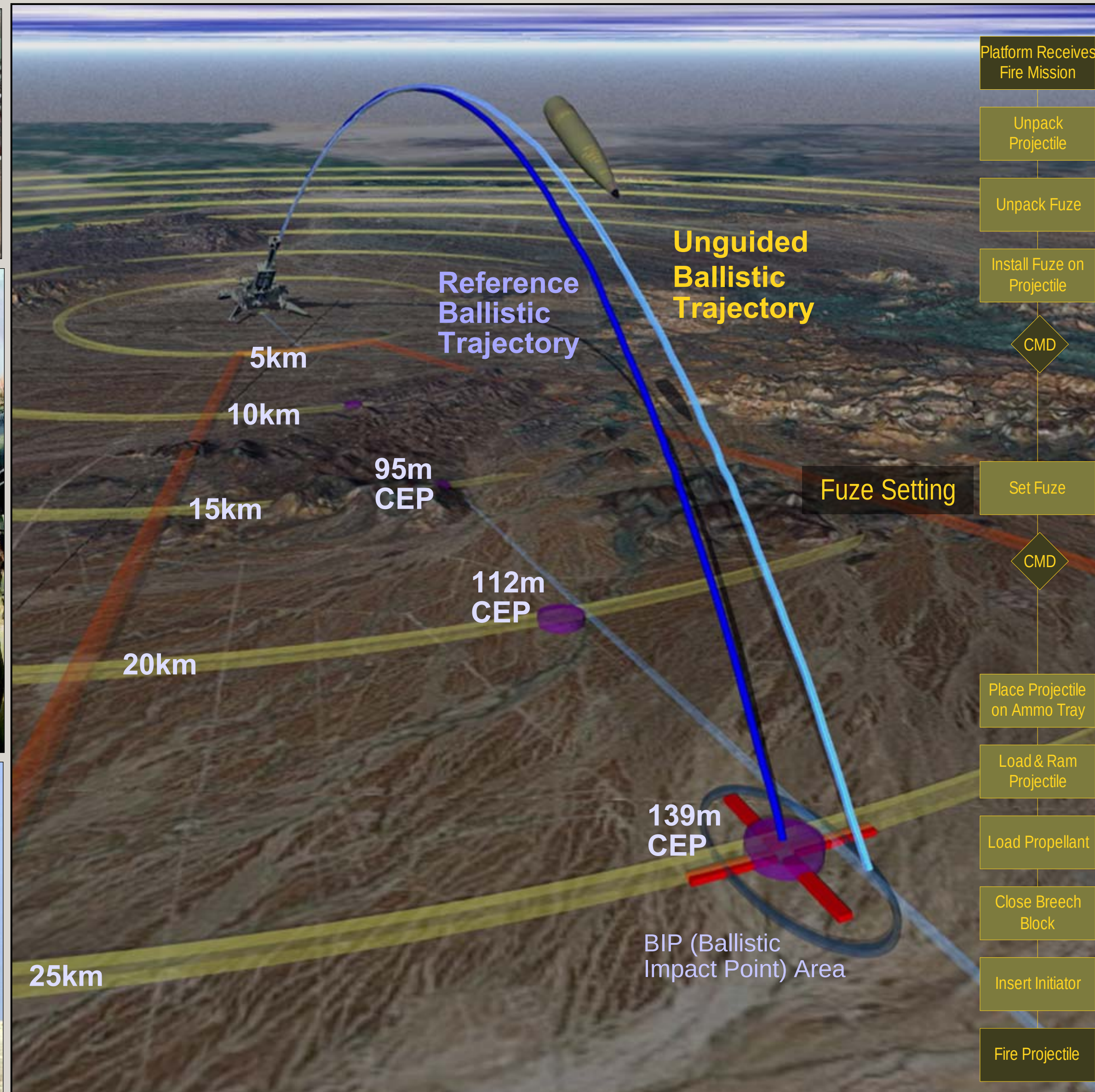

Precision PGK Mission

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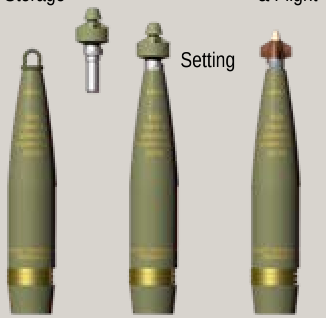
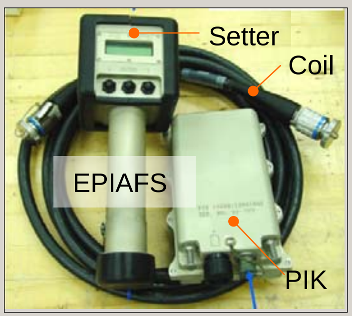
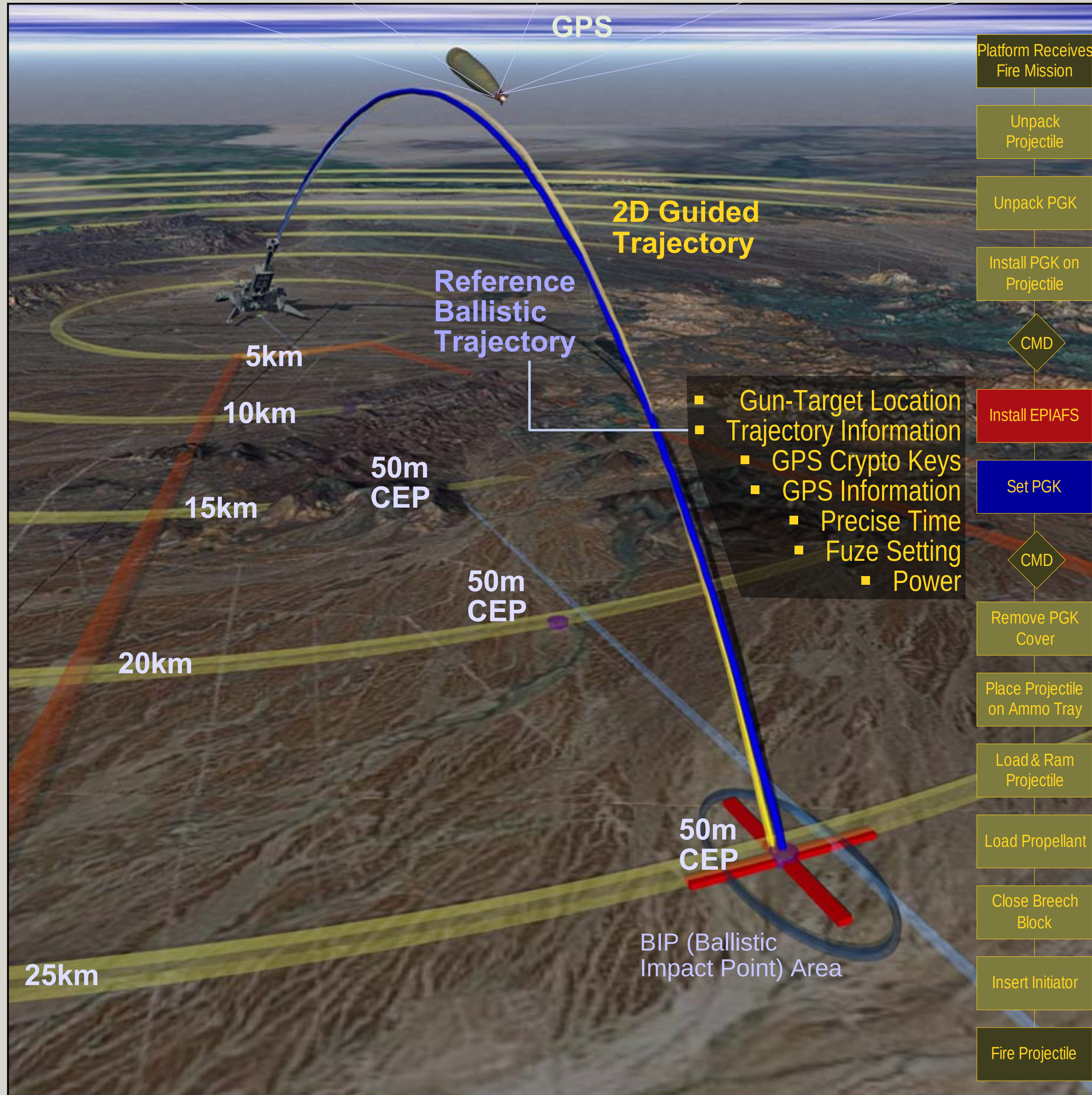


Planning the PGK Mission





What Level of Precision is Needed?

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- Housing Density Can Vary Widely Over Small Distances Between Terrain Elements
- Selecting Munitions with Increasing Levels of Precision May Be Most Cost-Effective

Operational Benefit

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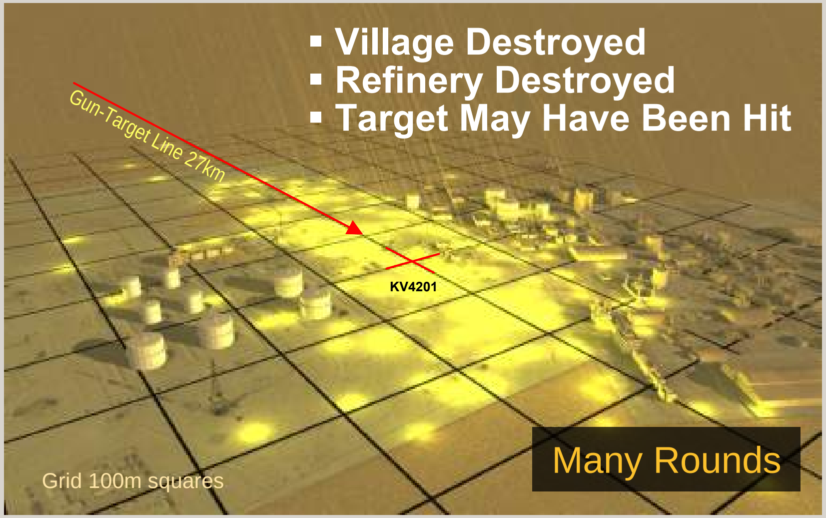
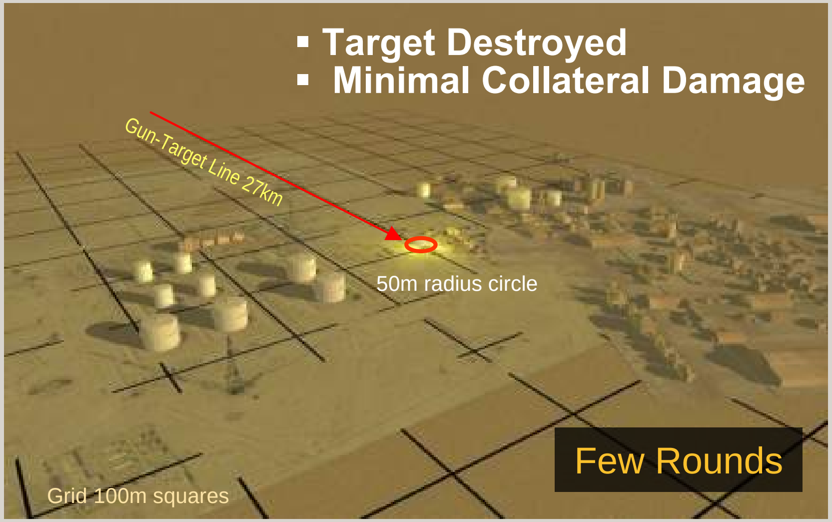
Today's Capability: 183m CEP*



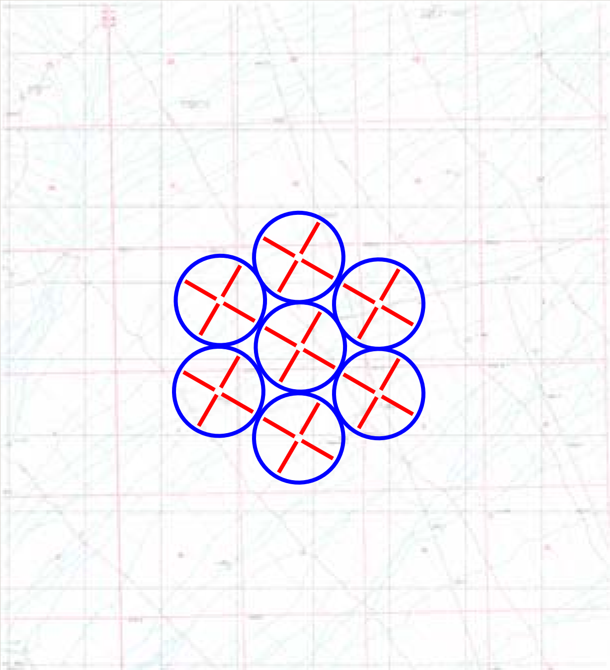
* M109A6 (Paladin) at 27km: 155mm (HE) M549A1

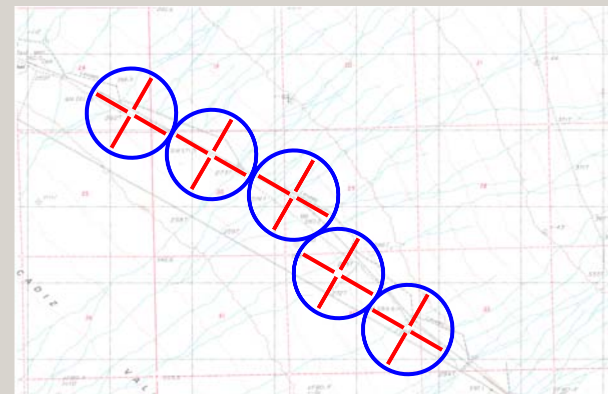
PGK: ≤ 50m CEP



- Improves Munition Accuracy
- Greatly Reduces Possibility of Collateral Damage
- Increases Number of Kills per Basic Load of Ammunition

PGK Missions





PGK performs the same missions as conventional 155mm HE munitions, but with better effectiveness consistent with a 50m CEP accuracy.

Logistics Cost is Driven by Tonnage/Volume

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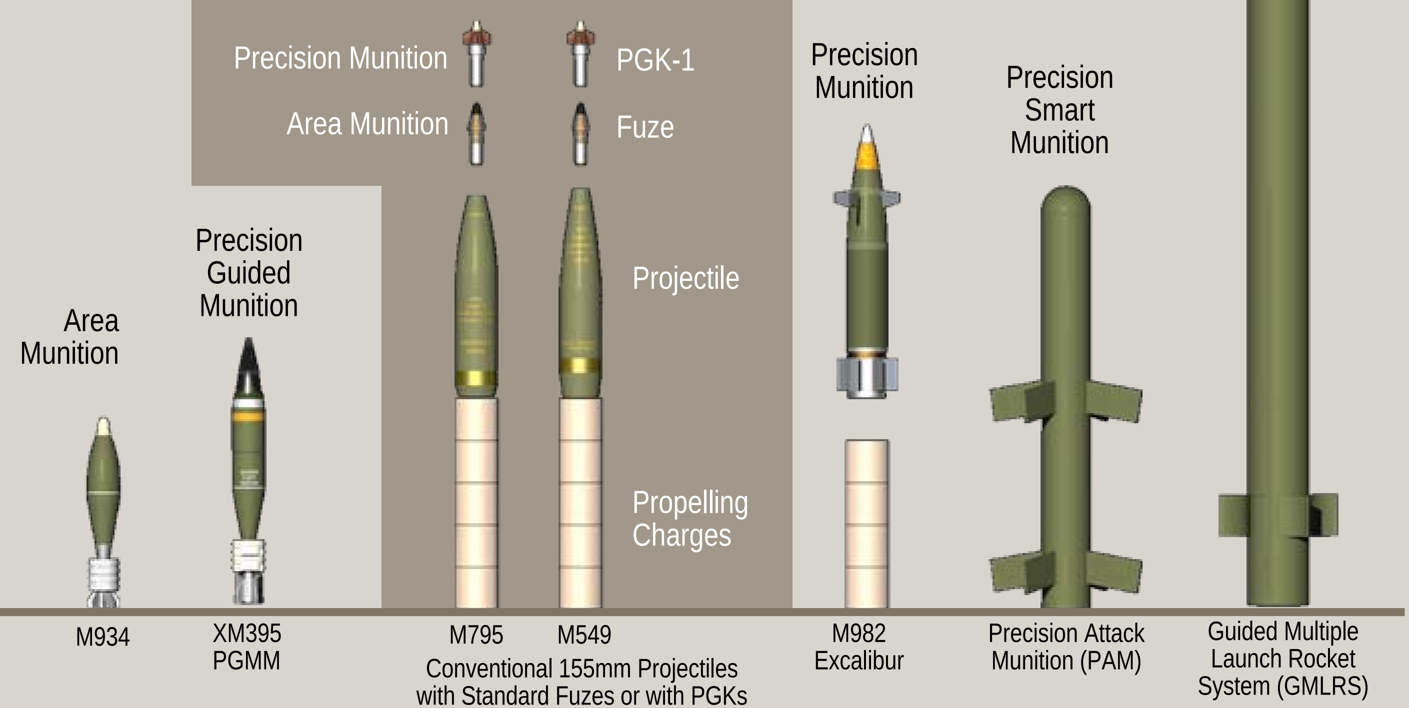
155mm Munitions Mix Can Be Established in the Field at the Fuze-Level,

Not at the Munition-Level

Unguided Conventional 155mm Projectiles Convert to a Precision Munition by Simply Replacing the Fuze with a PGK (Precision Guidance Kit)



Precision Reduces the Number of Rounds

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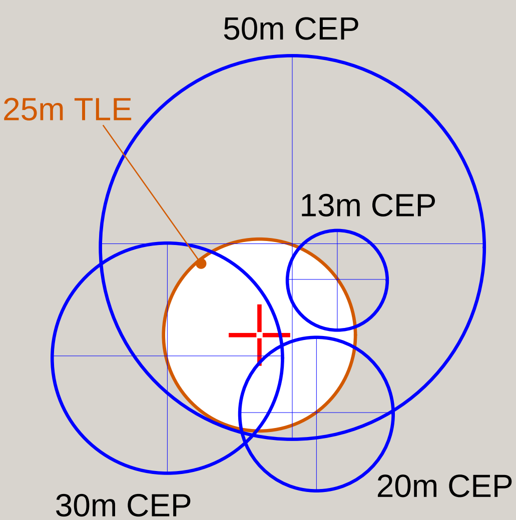
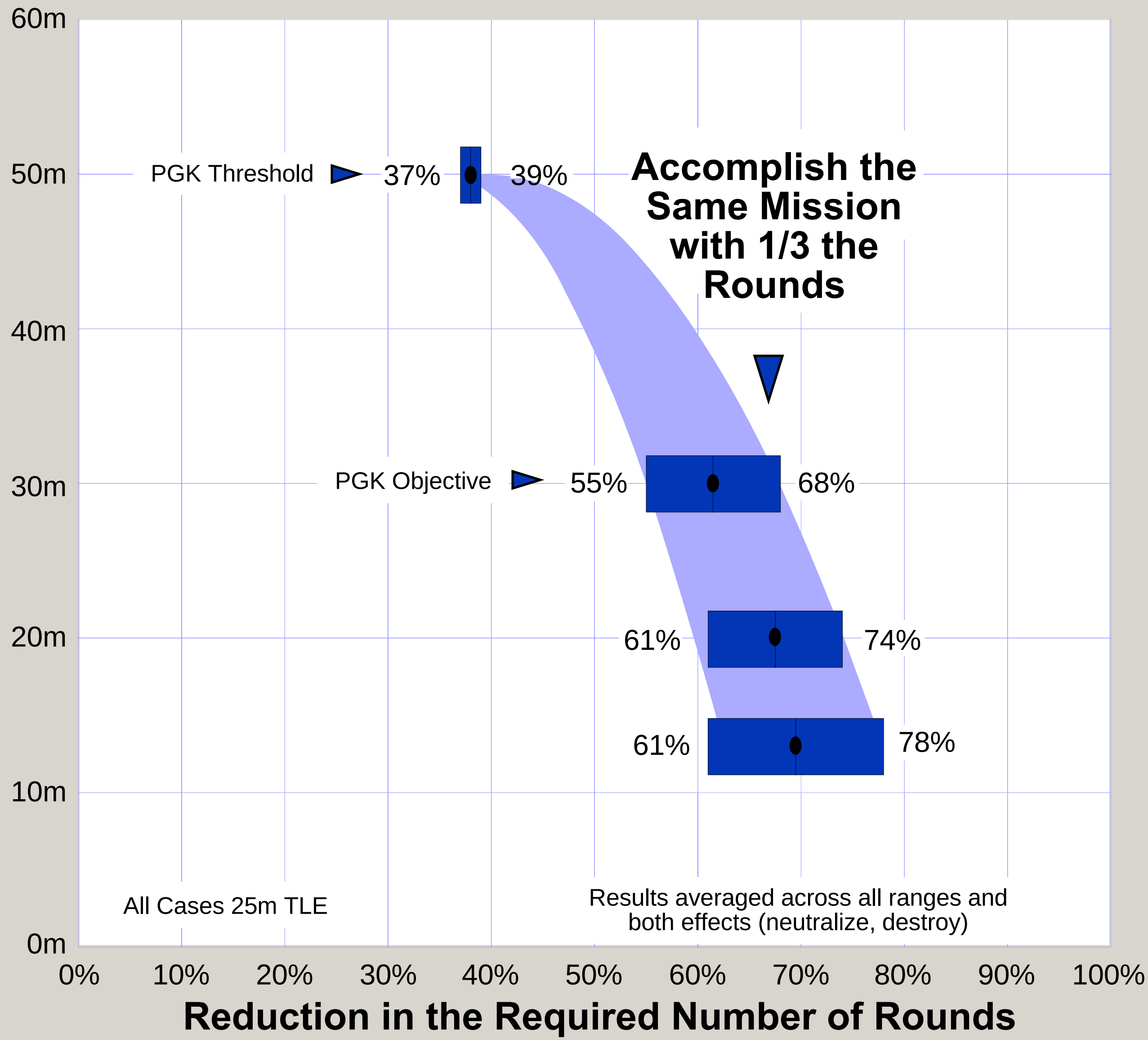
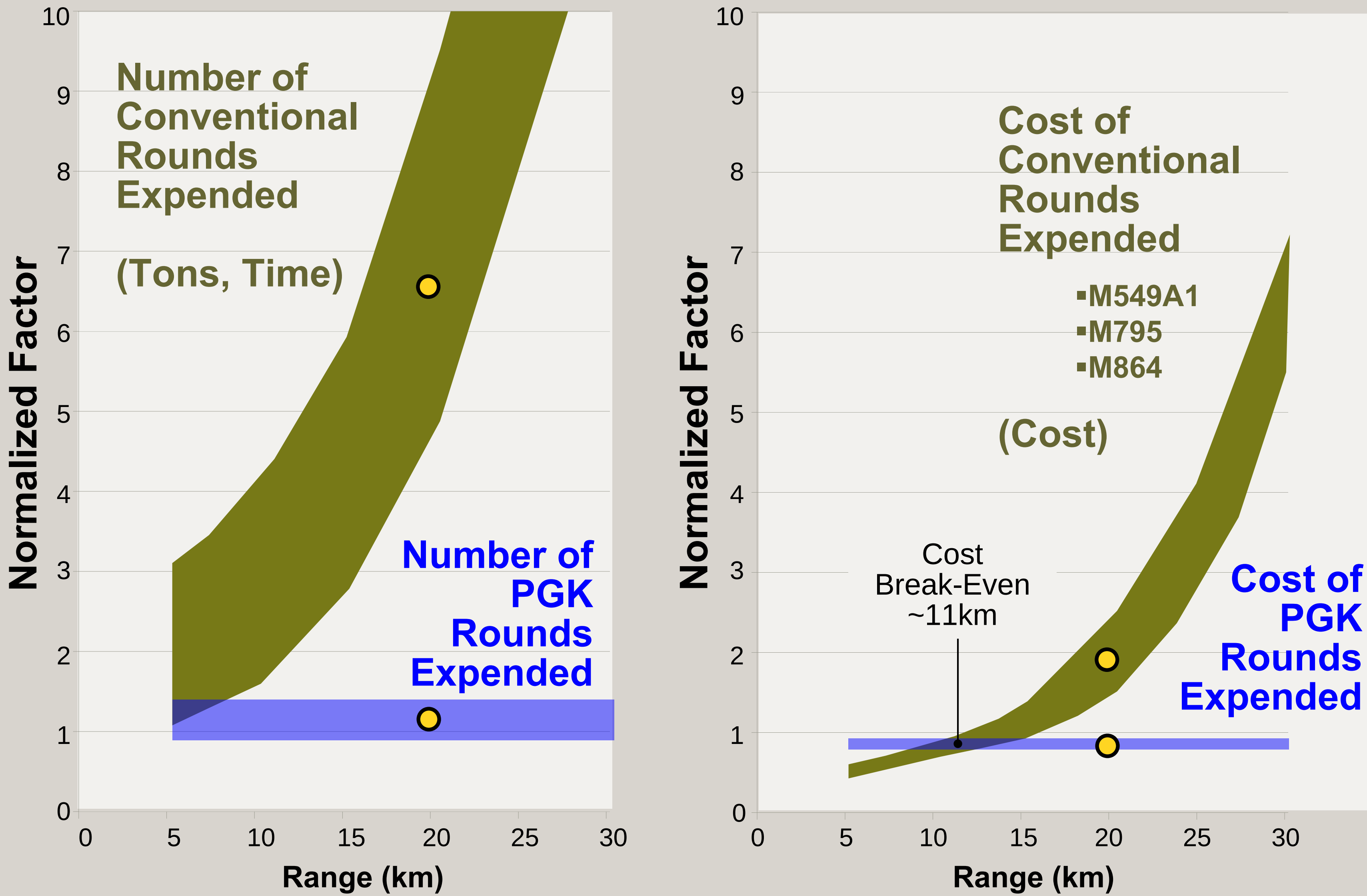
Accuracy of PGK Round (CEP)





PGK is Effective in Cost, Tons, and Time



Re-Supply Ammunition is Loaded by Hand

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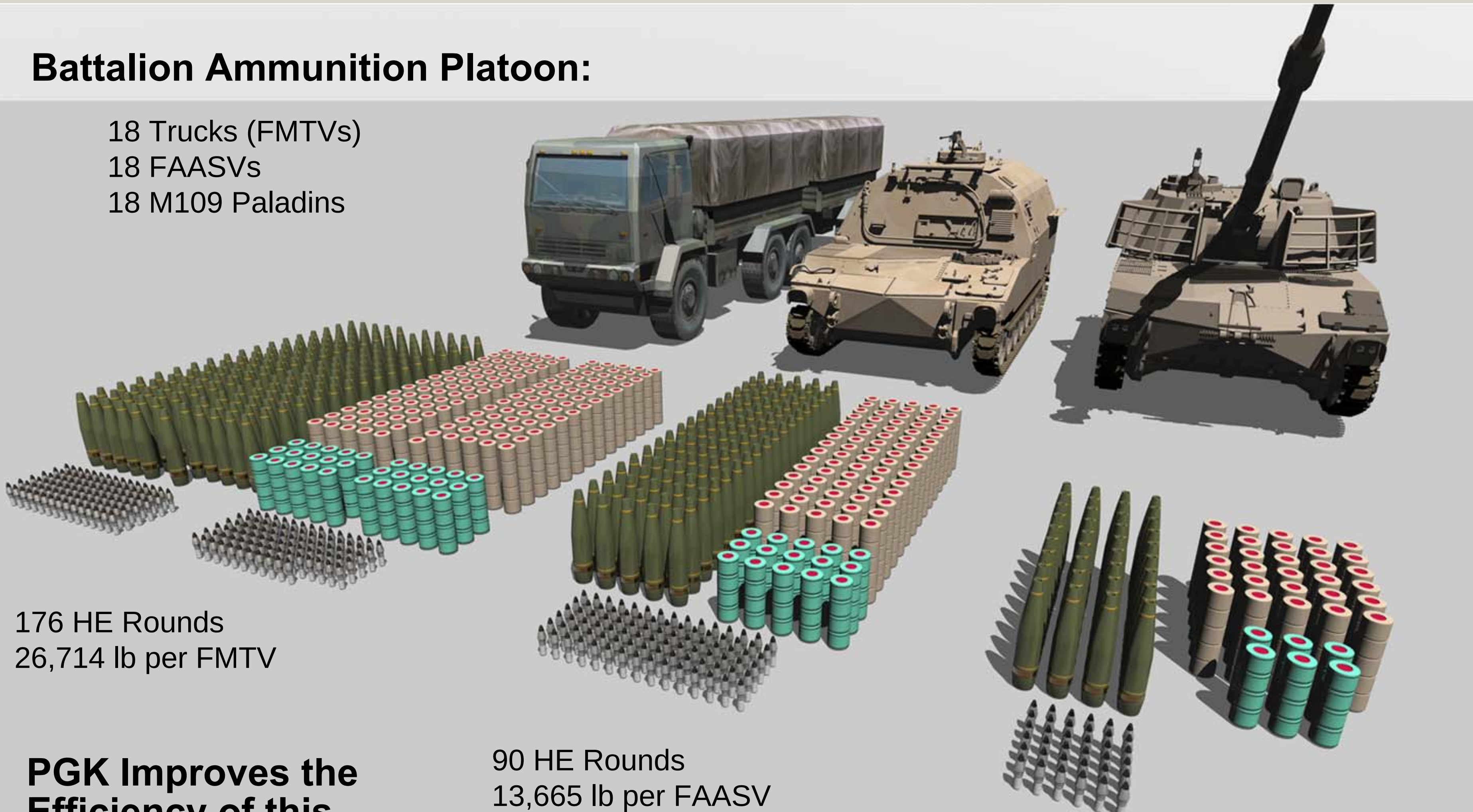
Battalion Ammunition Platoon:

18 Trucks (FMTVs)
18 FAASVs
18 M109 Paladins



176 HE Rounds
26,714 lb per FMTV

90 HE Rounds
13,665 lb per FAASV

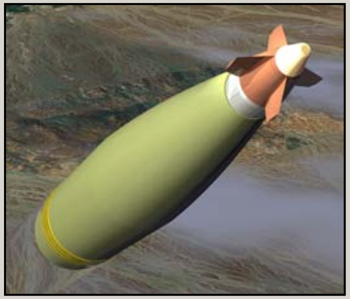
36 HE Rounds
5,466 lb per Paladin

PGK Improves the Efficiency of this Critical Supply System

Savings Across the Logistical Chain







Savings X Savings X Savings / Savings / Savings X Savings / Savings / Savings X Savings / Savings / Savings

- Transit Cost
- Loiter Cost
- Supply Chain

In Theatre Depot Costs

- Sortie Costs
- Re-Supply Costs

Fire Mission Cost

Round Cost

- Round Cost is Only a Small Percentage of the total Mission Cost
- Reduced Round Savings Has Multiplying Effect on Mission Savings

When the system and logistics costs are added to the cost of the rounds fired, a reduction of 55% to 68% in rounds fired makes an **all-precision stockpile a realizable goal.**

75% Reduction in HE Rounds for Same Effect

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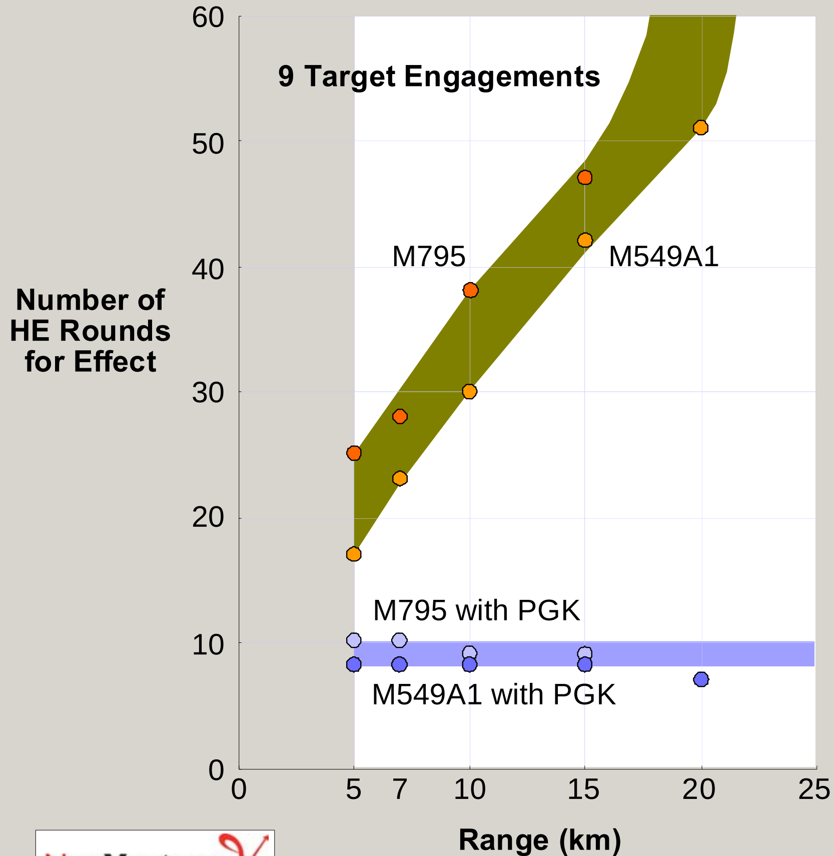
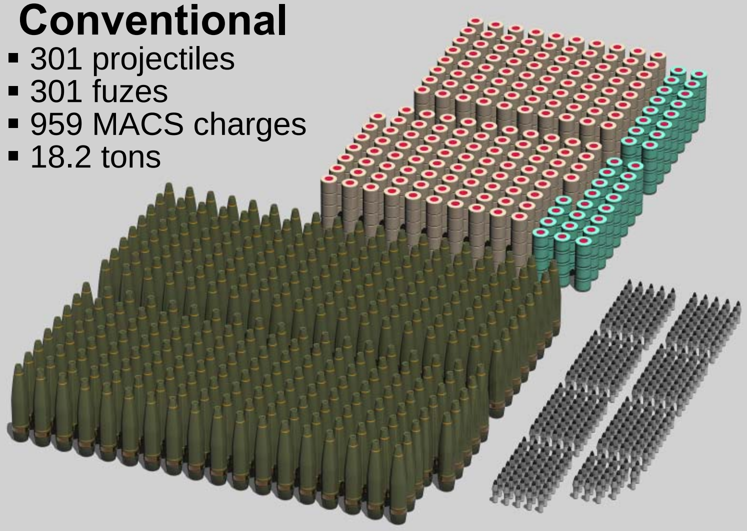


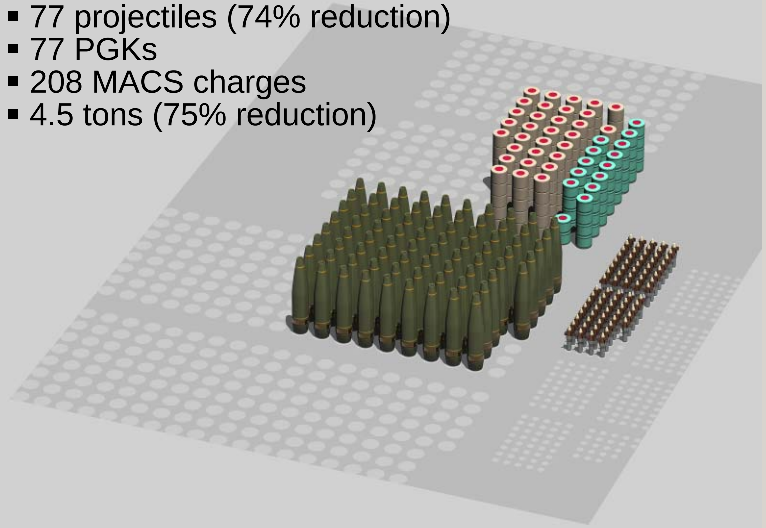
Conventional

- 301 projectiles
- 301 fuzes
- 959 MACS charges
- 18.2 tons



Conventional with PGK

- 77 projectiles (74% reduction)
- 77 PGKs
- 208 MACS charges
- 4.5 tons (75% reduction)



- Target Effect Takes Less Time
- Target Effect Costs Less
- Less Tons of Munitions Needed to Achieve Target Effect
- Longer Times Between Re-Supply
- More Targets Engaged with Less Collateral Damage

PGK is Affordable Precision

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Contact Information

An advanced weapon and space systems company

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Novel techniques for improved munitions development

44th annual Gun and Missile system conference

TNO | Knowledge for business

Gert Scholtes

Overview

- Introduction

- I Propellants and
- II Ignition of LOVA propellants
- III Multi-mode warheads and
- IV EFI systems

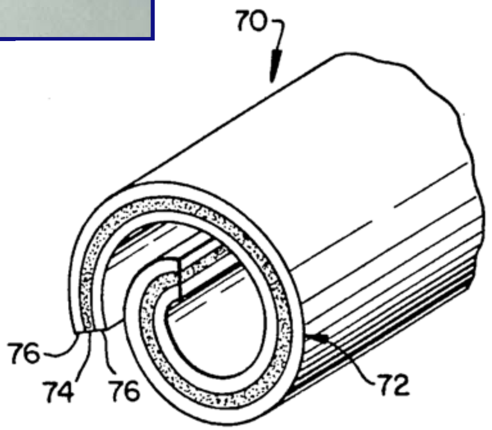
- Summary

Introduction

- Modern Military operations put high requirements on Munitions
- IM requirements (comparable performance)
- be inexpensive,
- Better performance (e.g. extended range munitions),
- decreased barrel erosion,
- temperature independent performance,
- Multi-mode or scalable functionality for MOUT intervention
- reliable (# UXO’s) and
- have a long lifetime

I Propellants

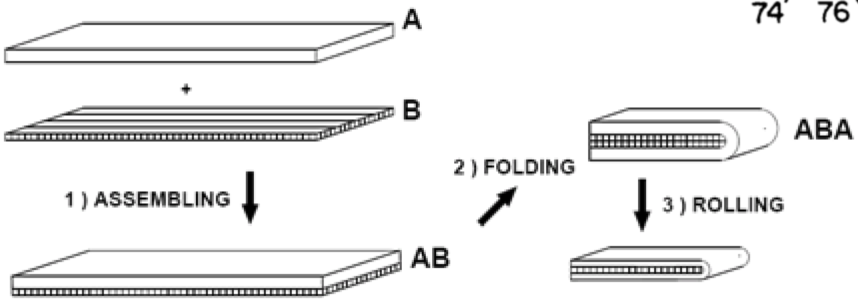
- Less Sensitive,
- more performance,
- decreased barrel erosion and
- temperature independent



- Solution: Co-layered propellants

- Advantage: improvement of gun performance by enlargement of the impulse on the projectile

- Manufacture:



- Disadvantage:
  - Difficult
  - Time-consuming

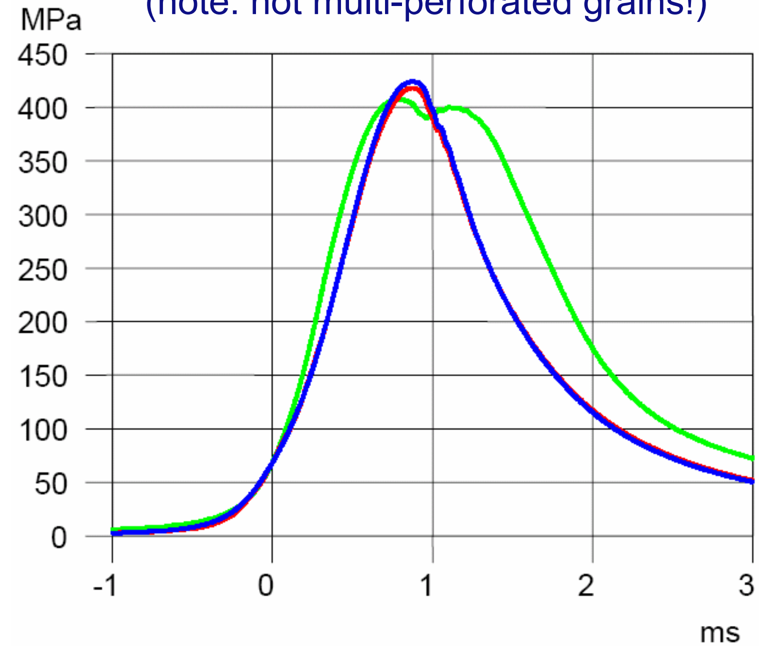
- **TNO's approach: co-extrusion**

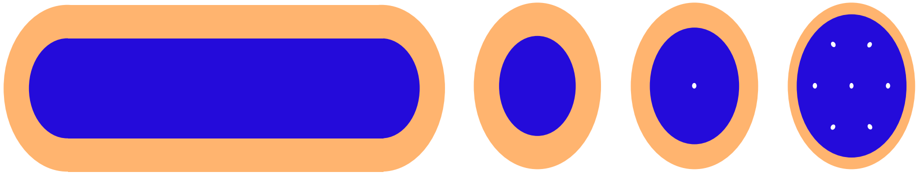
Co-layered propellants

(some) Advantages

- Increased performance
- Decreased erosivity of high energy propellants
- Increased ignition behaviour (e.g. LOVA propellants)
- A wide variation in geometries-> implying a larger number of possible applications

Ritter, ICT 2007
(note: not multi-perforated grains!)

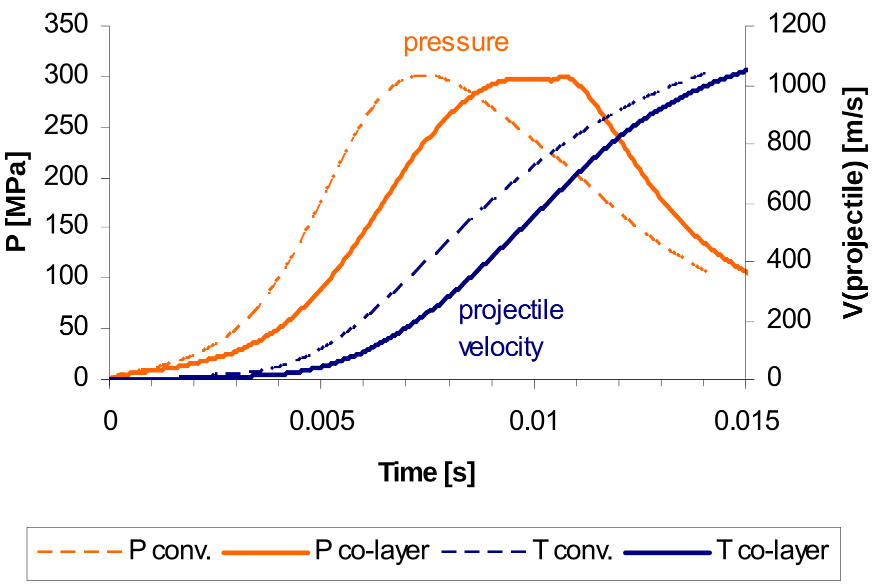


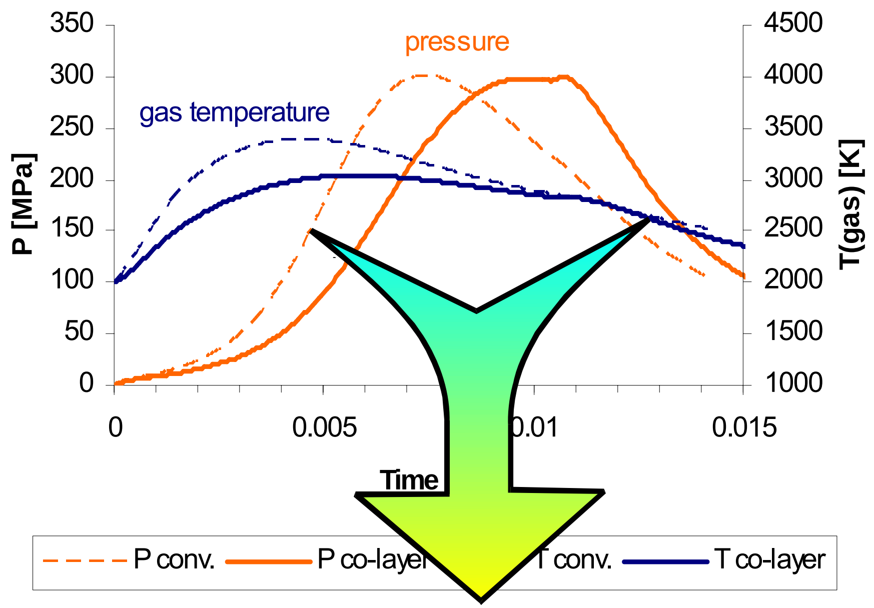


Performance: Co-layer vs. Conventional

- Examples of simulated performance effects

2 propellants: 7-perf; T_f(core) = 3515 K; T_f(layer) = 2900 K
factor burning rates = **2**



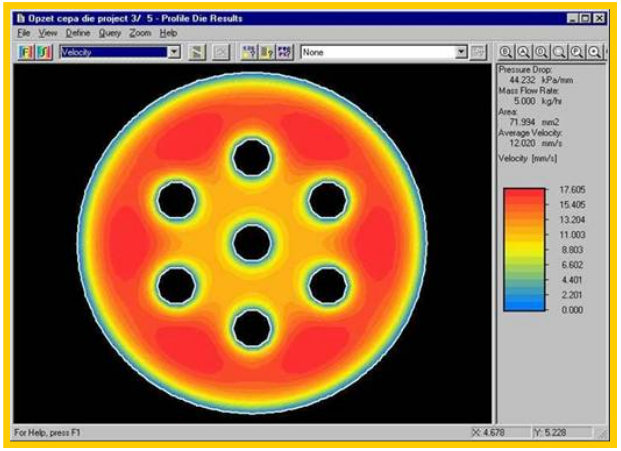


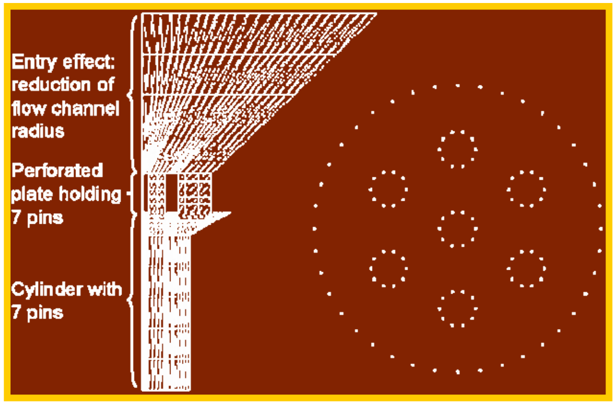
→ T_{max} = 3040 K
= 3385 K without 'cool' outer layer

Barrel lifetime increase ≈ factor 2

Results of Co-extrusion of co-layered propellants at TNO

- Improved die-design using special simulation software in 2007 (applying available knowledge from polymer processing)
- Die is very important for this process





Co-extruded LOVA propellant

Co-extruded DB propellant

Results of Co-extrusion of co-layered propellants at TNO

Bond integrity at high pressures:

→ Closed vessel tests with DB single-perforated co-extruded grains

- Manufacturing:
  - Excellent distribution of both layers
  - Excellent bonding
  - Also at high pressure (260 MPa)

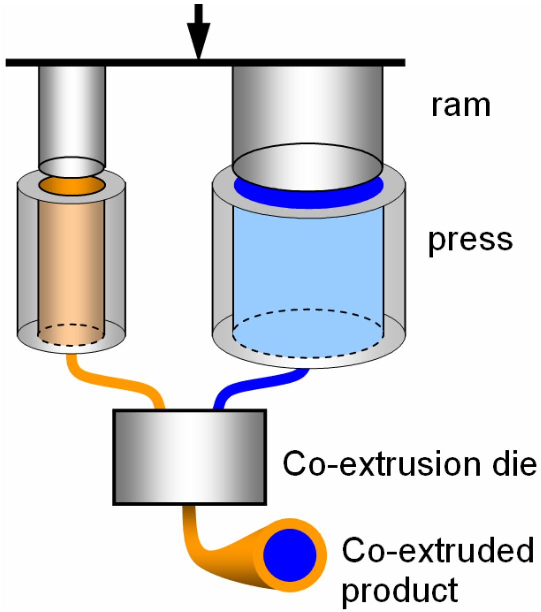
6.8 mm

Future developments

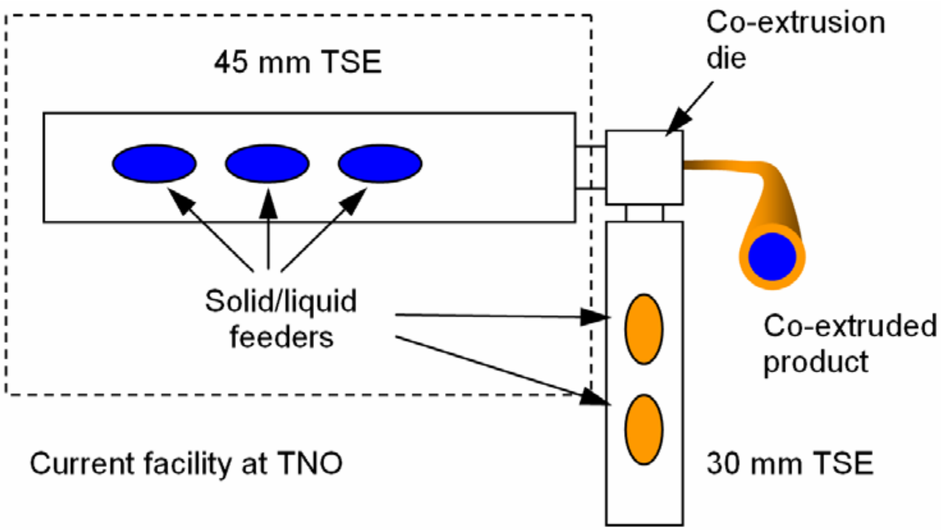
- Double ram press

Alternative ram extrusion set-up

- Well controllable process
- Inner and outer layer can be variable (i.e. composition and size)
- No dramatic change of facilities

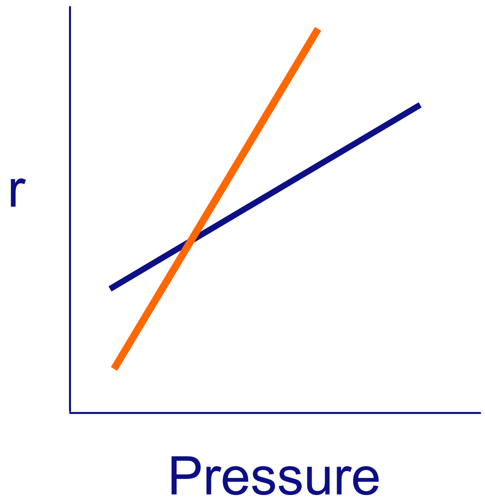


- Continuous co-extrusion (twins-screw extruder)



II Less vulnerable: LOVA propellant-> ignition problem

- LOw Vulnerability propellants
- Burning behaviour (Vieille's law): $r = \beta \times P^{\alpha}$
  - Conventional (NC-based) $\alpha \approx 0.6 - 1.0$
  - 'LOVA' (RDX-based) $\alpha \approx$ **1.0 – 1.4**
- Two-step ignition process:
  - Endothermic pyrolysis of binder
  - Exothermic combustion



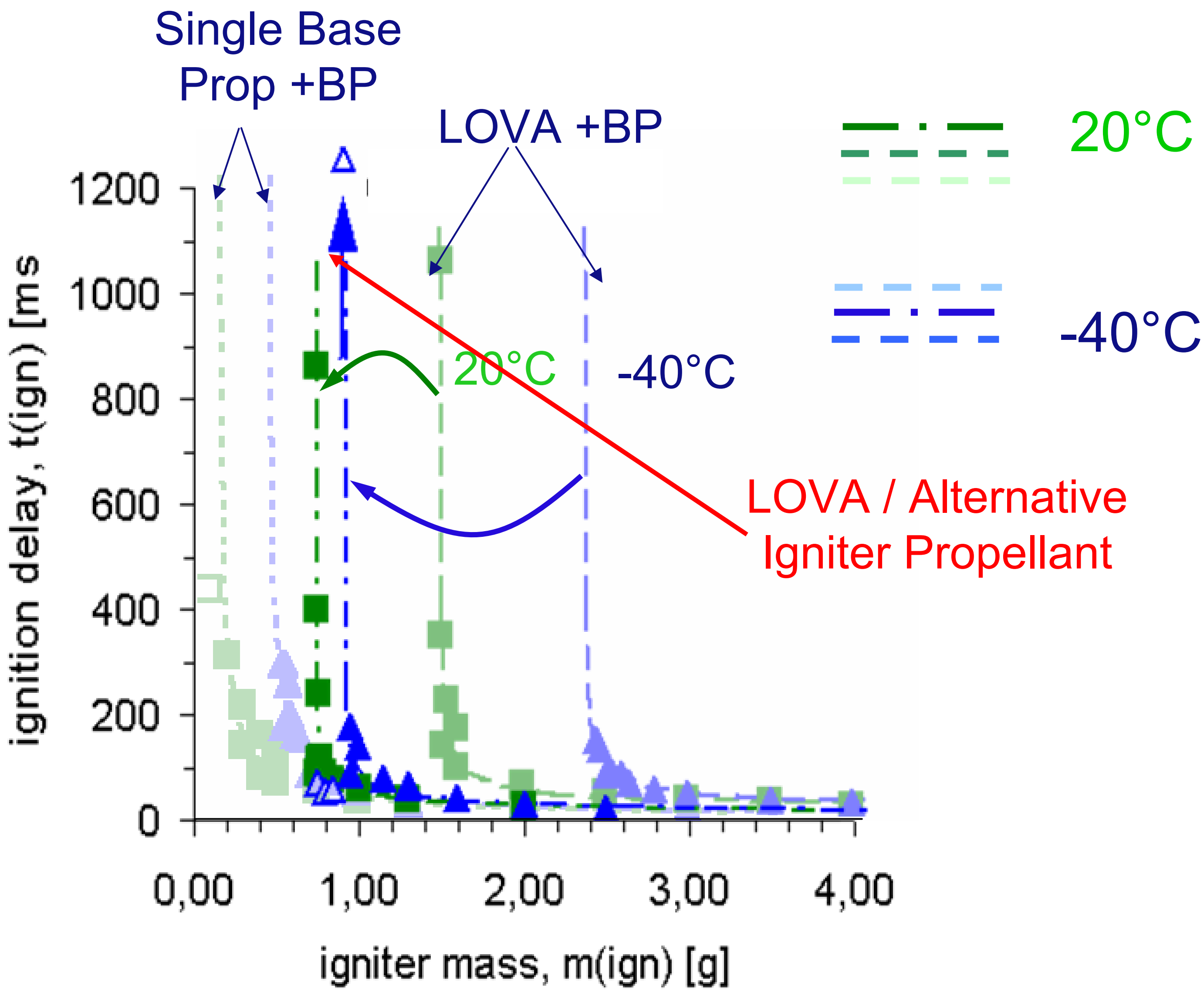
→ ignition phase LOVA's: low pressure → low burning rate → **lengthy and variable ignition delays**

Test results – mis-fires

- Mis-fire: insufficient igniter output for ignition of the propellant

- Grain surface melts initially, recovered grains stick together
- Tiny droplets of igniter (BP) combustion products on grain surface

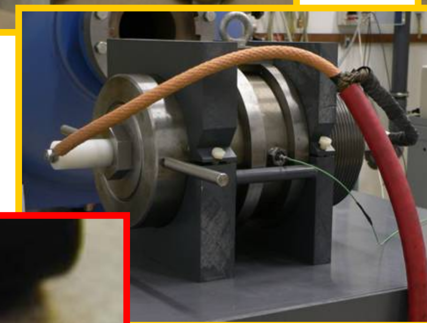
Ignition delays and improved igniter composition



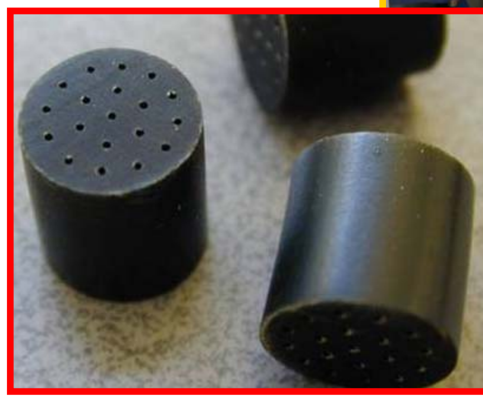
Propellants: Testing facilities

- Closed Vessels
- Erosivity & burning interruption tests
- Gun simulator
- Laboratory Guns
- Plasma ignition





Closed VesselsV's (25 – 700cc)



45 mm twin-screw extruder

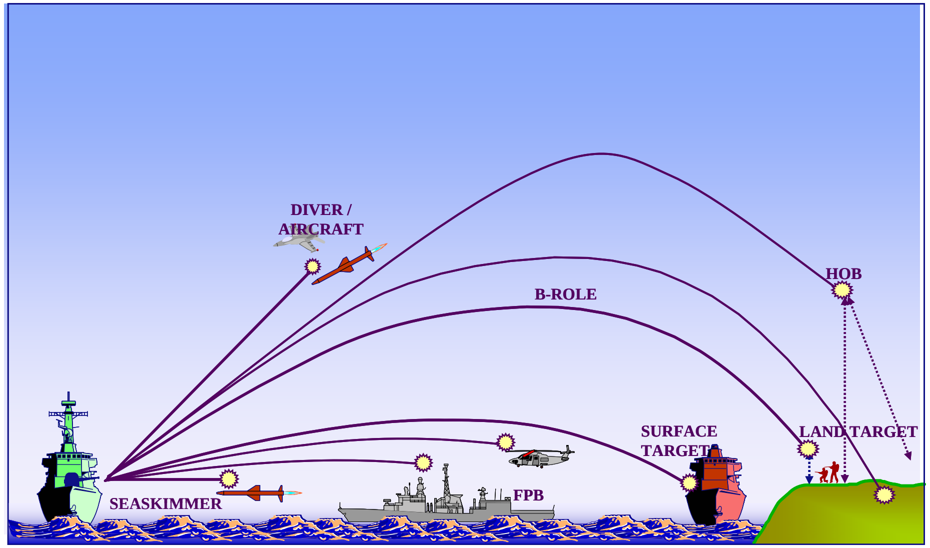
Plasma ignition

Vented HPCV and catch tank

III Multi-mode warheads

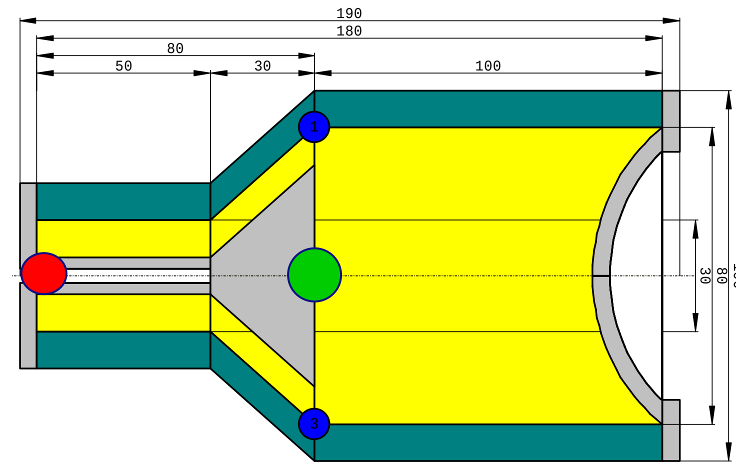
- Solutions:
  - Programmable fuzes
  - Warhead design
  - Complex ignition systems

- The MEDEA programmable fuze is intended for use against (see Figure):
  - Fast patrol boats FIAC
  - High diver missiles
  - Sea skimming missiles
  - Fixed wing aircraft
  - Rotary wing aircraft
  - Surface vessels



Multi-mode warheads: e.g. EFP

- Changing location of ignition
  - EFP mode
  - Streched EFP
  - Fragments
  - Aimable warhead



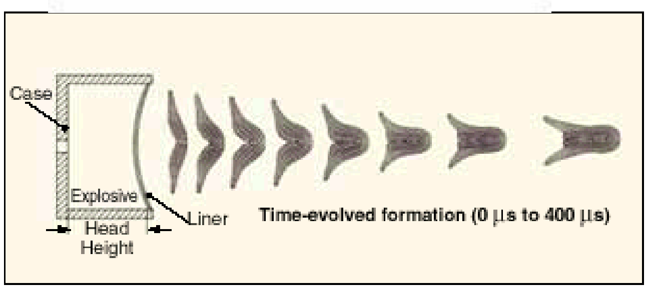
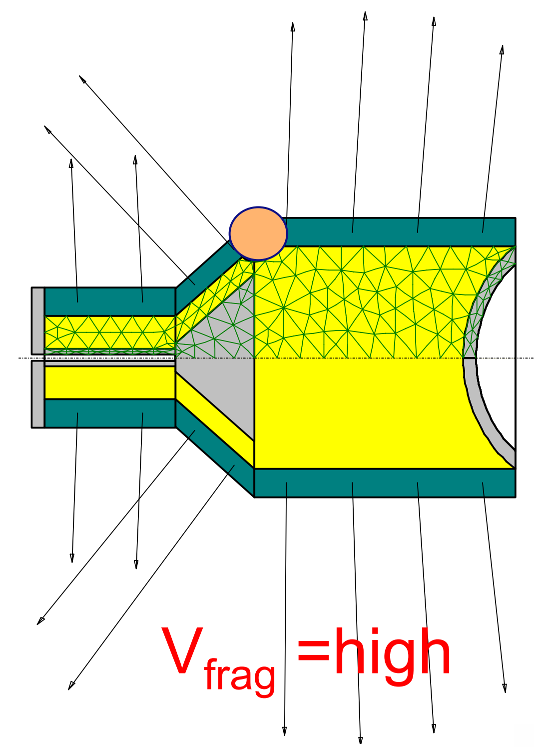
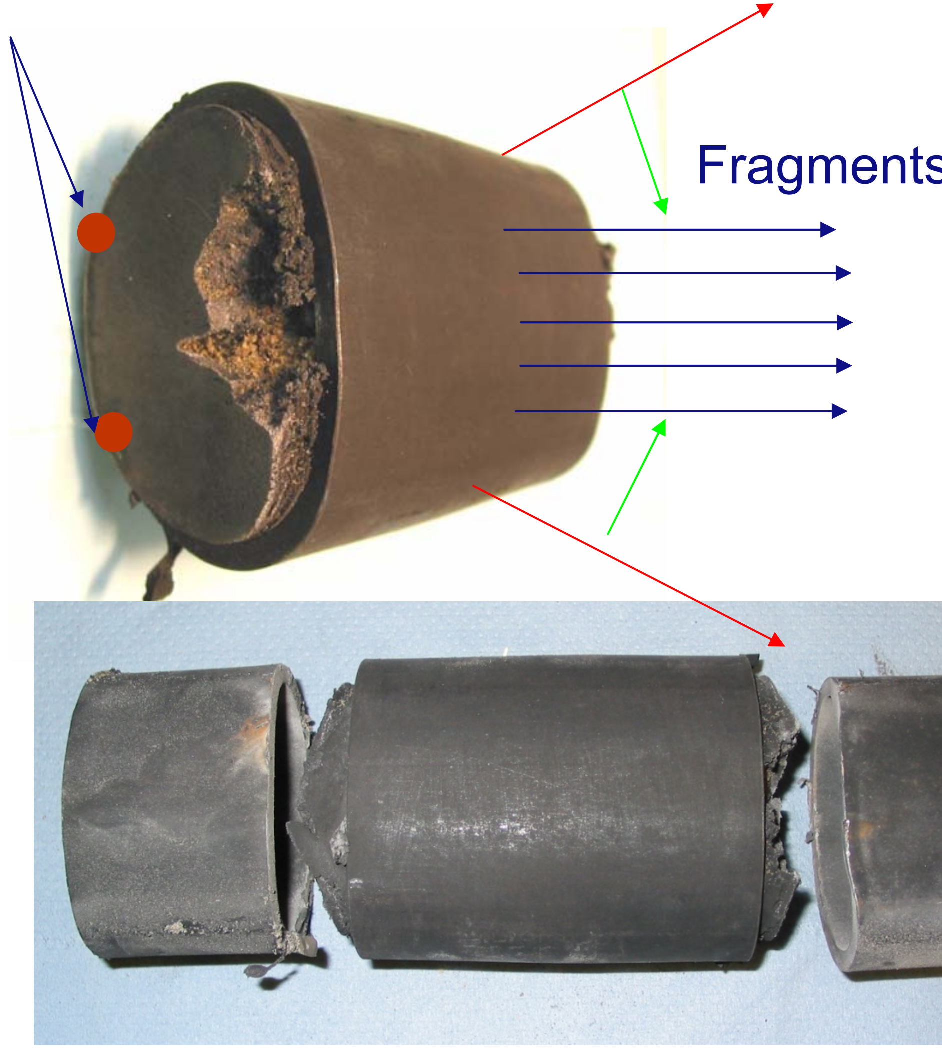


Figure 1. Formation of an EFP warhead

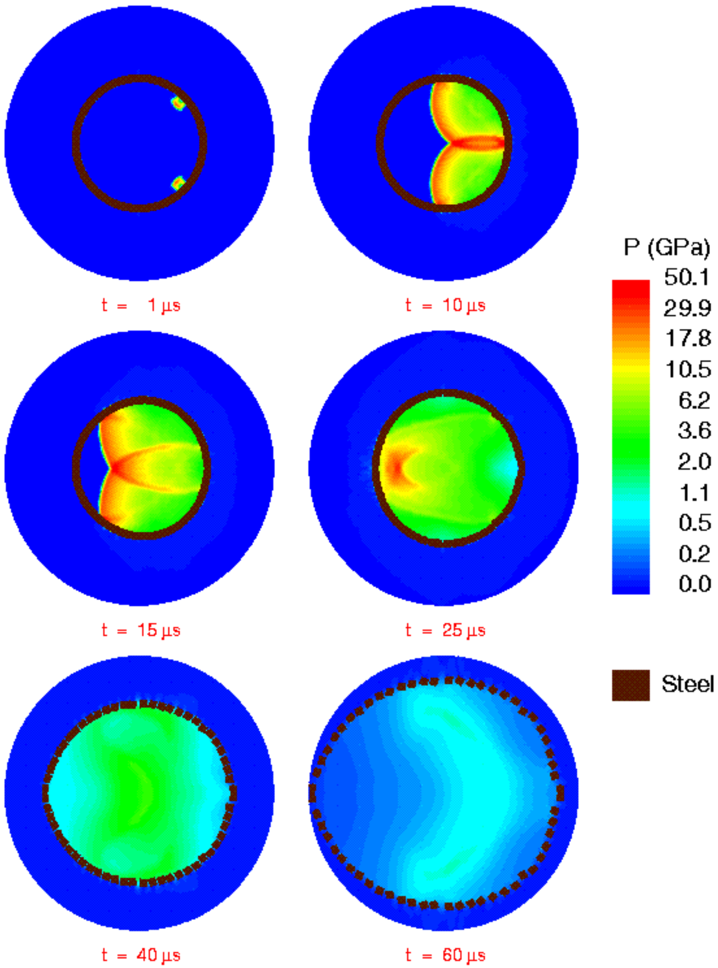


Forming of warhead (aimable)

- 3 mm plastic explosive, buffer: 1 layer rubber (PBXN-109)
- After forming: ignition



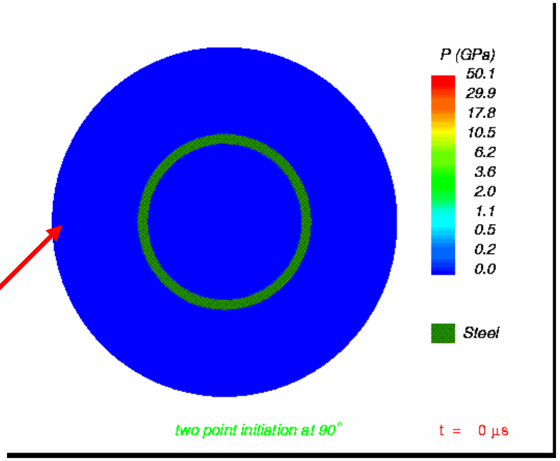
Aimable warheads: 2-Point initiation vs single



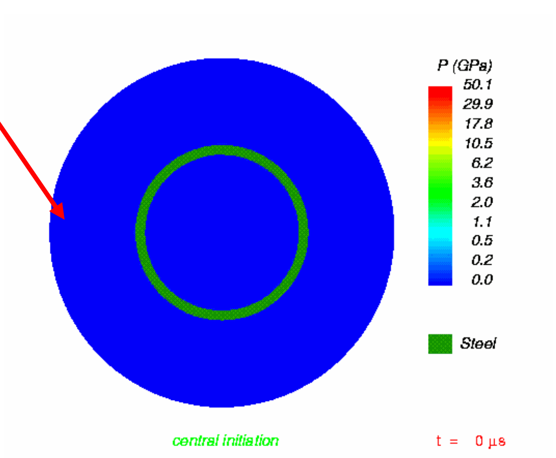
two point initiation at 90°

V_{max}= 2700 m/s

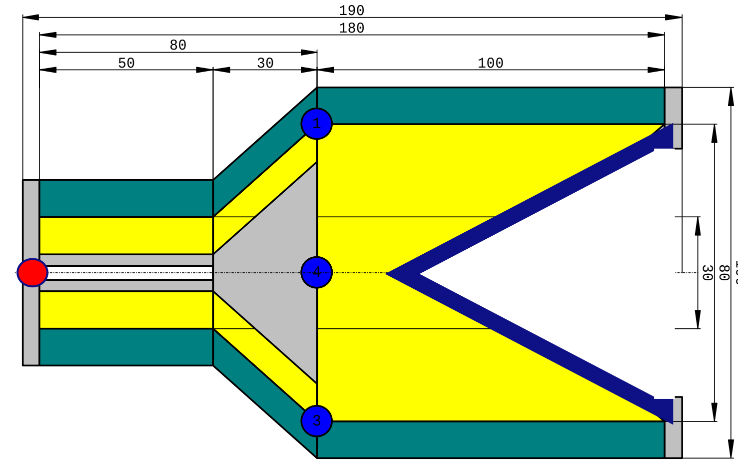
Fragment velocity



V_{max}= 2000 m/s



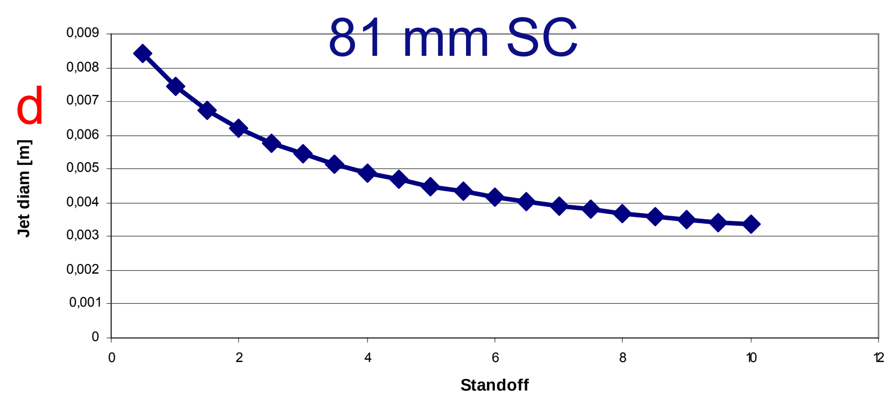
Multi-mode warheads: e.g. SC



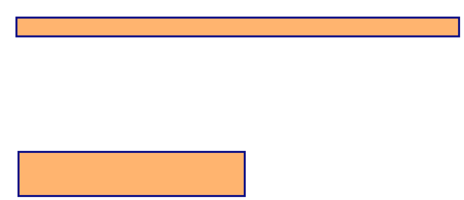
- Shaped Charge or
- EOD Shaped Charge

- Initiation of Explosives
- v^2d=constant [Held criteria]
- V= velocity of tip and d = diameter of jet (V in km/s and d in mm)

- PBXN109: 49 BSDT
- I-PBXN109: 92 BSDT



- For penetration: long jet -> small diameter
- For EOD: v^2d max. so short stand-off -> large diameter
- Timing of igniter
- But timing is crucial; Solution:



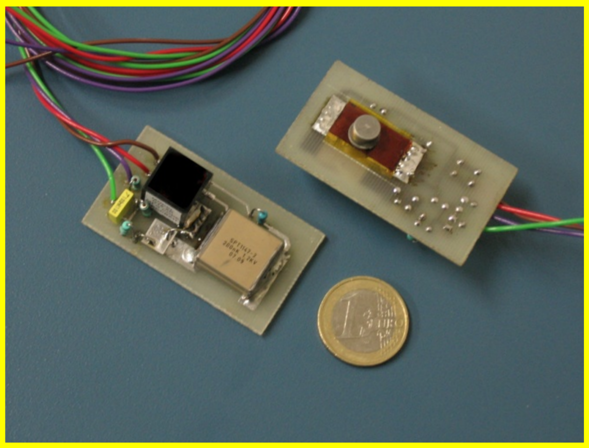
EFI Igniter

IV Why an EFI system

- An EFI is intrinsically safer than standard initiators (no primary explosive)
- More reliable (So, no UXO's)
- Works much faster < microseconds (µs)
- Can be smaller (near future)
- Is compliant with new STANAG (4560) regulations
- New opportunities (tandem charges, aim able warheads etc.)

- Disadvantage : More expensive (at the moment)

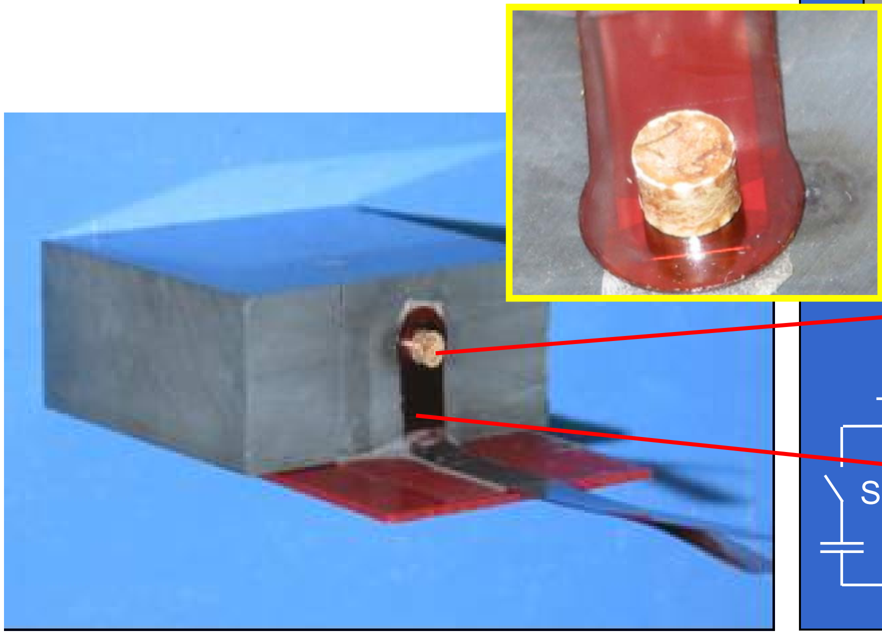
- Future: Micro Chip EFI (McEFI) → inexpensive

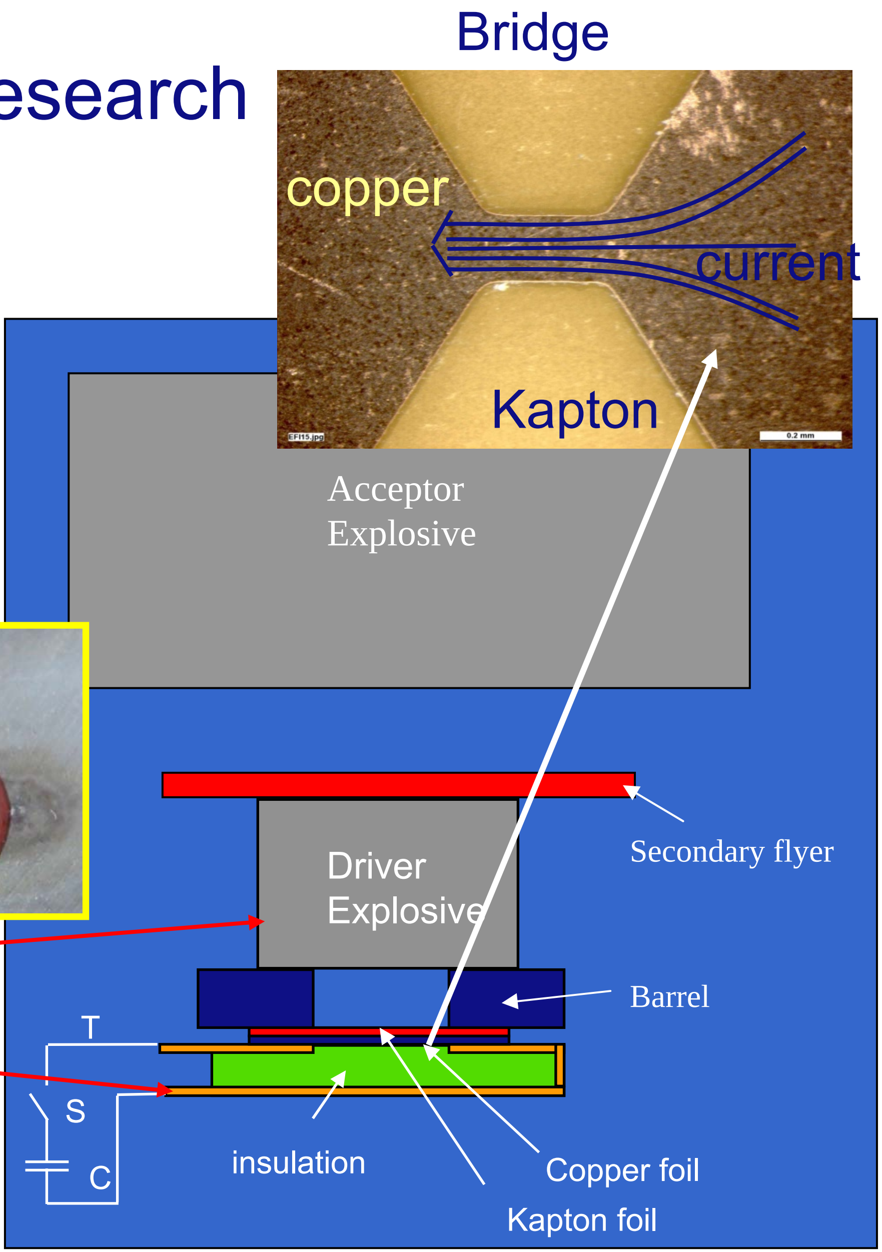


5 x 5 mm pellet

Exploding Foil Initiator Research

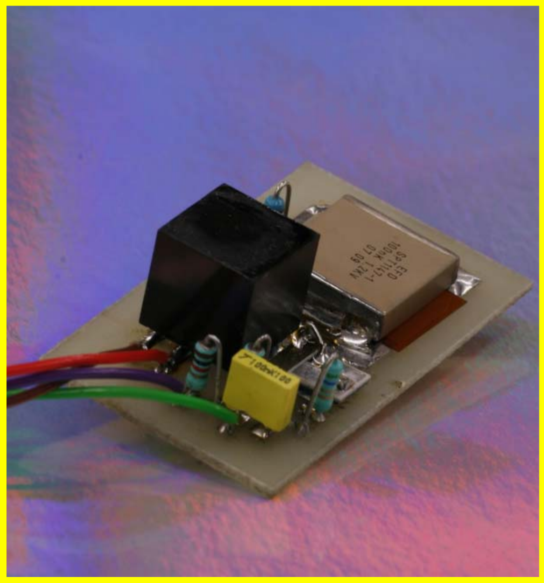
- Exploding foil
- Electrical circuit
- Velocity of the flyer
- Driver Explosive
- Secondary flyer
- Acceptor explosive





Conclusions mini EFI and Mc EFI development platform

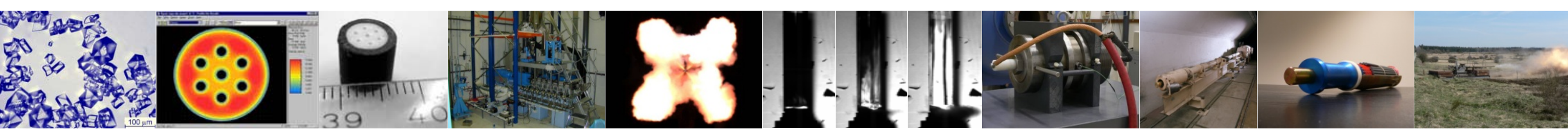
- A very efficient electrical circuit (η = 50 → 90%)
- Mini-EFI Works at Voltage < 1300 Volt (Solid state switch)
- With “of the shelf components” small IM compliant EFI-detonators can be built (~8cm^3 including High Voltage-supply)
- Secondary flyers makes the detonation train more reliable (in case of set-back)



- Successful initiation of TATB and RDX with several types of flyer materials
- Combining the EFI with the ESAD with Micro Chip technology can make a small and cost effective unit
- Solution for complex ignition system (multi-mode warheads)

Summary

- Modern Military operations put high requirements on Munitions
- Innovation in munitions' development can give the answer, examples:
  - Co-layer propellants (co-extrusion)
  - Ignition of LOVA propellant
  - Multi-mode warheads and programmable Fuzes
- Technical solutions can help to address the challenges for your future munition developments



- TNO Defence, Security and Safety

- The Netherlands

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BTERM II -- 5” Gun Launched Projectile

44th Annual Gun & Missile Systems Conference and Exhibition

8 April 2009

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DISTRIBUTION STATEMENT A. Approved for public release; distribution is unlimited.

Approved by Michael A. Till, Deputy Department Head Engagement Systems Department

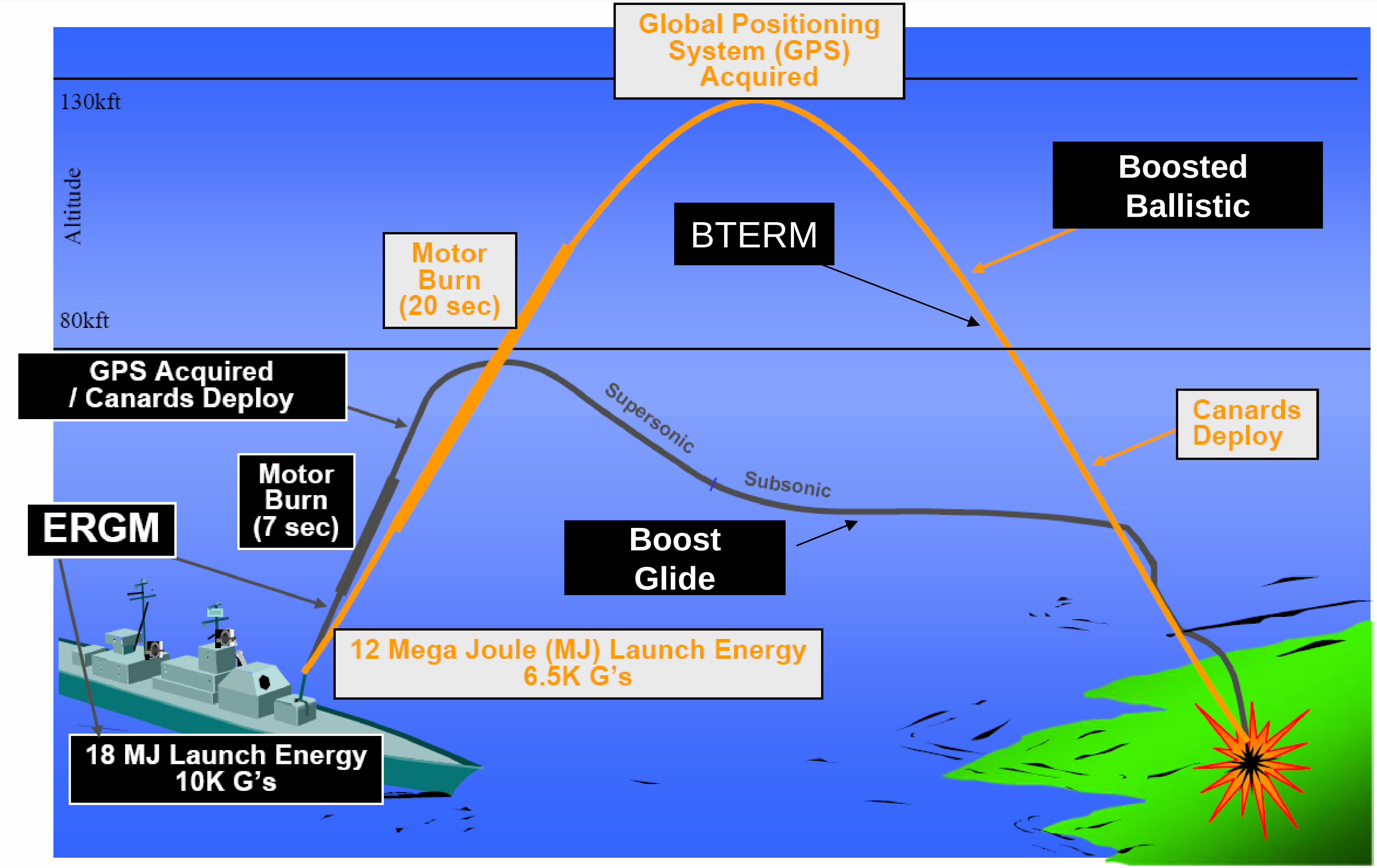
Agenda

- System Overview
- Major Subsystems
  - Rocket Motor
  - Low Cost Guidance Electronic Unit (LCGEU)
  - Canard Actuation System
  - Warhead
- Recent Tests
- Program Accomplishments

Ballistic Trajectory Extended Range Munition (BTERM)

- Flies a primarily ballistic path, correcting for
  - Gun pointing errors
  - Winds aloft
- Compatible with MK45 Mod2 and Mod4 guns
- Technology demonstration effort funded by the Navy
- Proven success in boosted and un-boosted guided flight tests

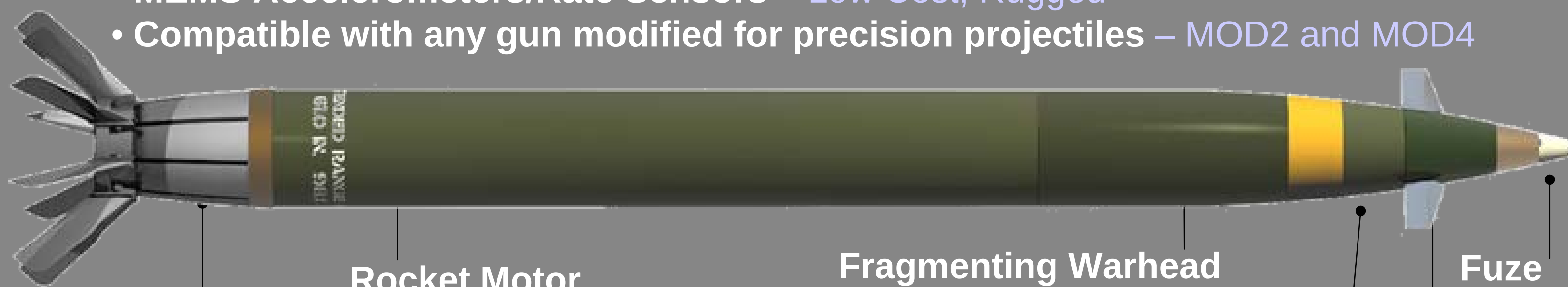
BTERM Mission Profile



NAVSEA WARFARE CENTERS DAHLGREN

System Overview

- **Boost-Ballistic Trajectory** - Long Range, Fastest Flight to Target
- **Rolling Airframe with Single-Axis Control** – Small Delivery Errors
- **Rear Obturation** – Simple, Robust Rocket Motor
- **High-Density Frag Warhead** – Lethal Across Target Set
- **GPS with Anti-Jam** – Short Time in Jammed Zone
- **MEMS Accelerometers/Rate Sensors** – Low Cost, Rugged
- **Compatible with any gun modified for precision projectiles** – MOD2 and MOD4



Rocket Motor
- End-Burning with Centerport Inhibitor
- SAA-139 Propellant
- Titanium Beta-C Rocket Motor Case

Fragmenting Warhead
- Warhead
- PBXN-9 Explosive
- Warhead S&A (Safe & Arm)
- Booster Cup and Detonator

Fuze
- Gun Interface
- Safe Separation
- HOB Sensor

TFA (Tail Fin Assembly)
- Blast Tube/Rocket Motor Nozzle
- ISD (Ignition Safety Device)
- 8 Taper Fins
- Fin Locking Mechanism

GEU (Guidance Electronics Unit)
- ISA (Inertial Sensor Assembly)
- GPS Module/Anti-Jam Module
- Flight Processor Module
- PCE (Power Conditioning Electronics) and I/O

CAS (Control Actuator System)
- COTS Servo Motor
- Battery Pack (8 Storage Batteries)
- Canard Deployment Mechanism

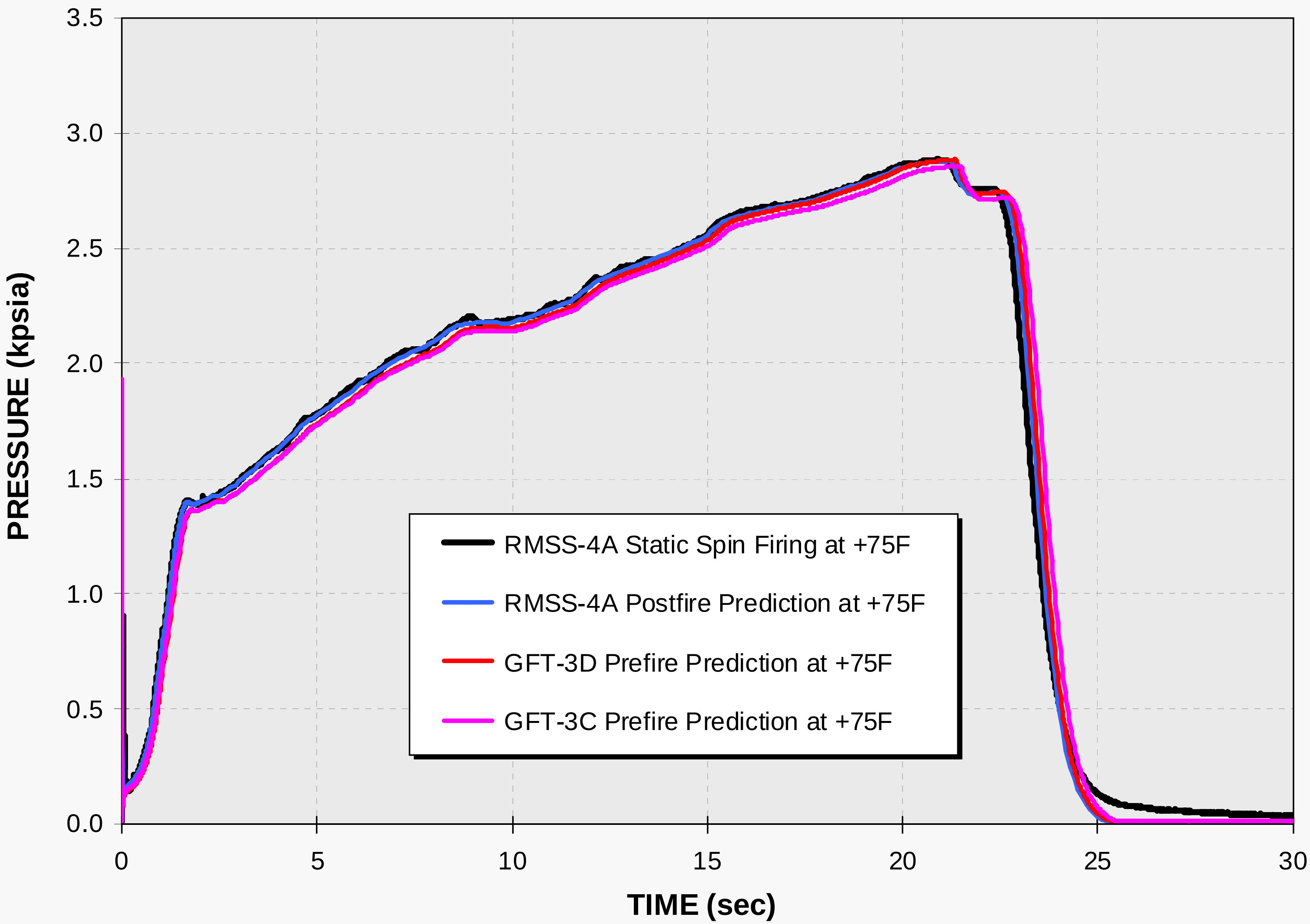
Rocket Motor

- Many subsystems on BTERM II had been proven during BTERM I and ANSR which were predecessors to BTERM II
- Changes were implemented in the manufacturing processes towards a more producible design
- The rocket motor was a pacing factor that required significant and unplanned attention
- Two areas were improved over a 2 year span and ultimately proven successful
  - Over pressure during testing
  - Nozzle burn-through

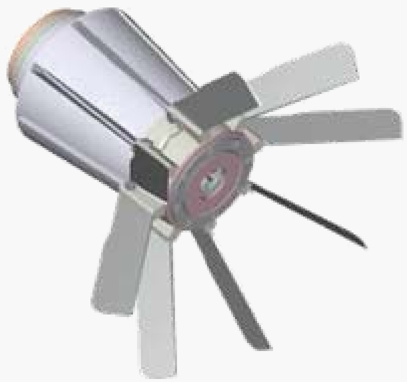
BTERM II Rocket Motor Summary

- BTERM II motors have exhibited two different anomalies
  - Over pressurization
  - Blast tube insulation burn through
- These only occurred in flight or spin tests, not static
  - Anomalies are associated with unanticipated interaction between environments and process/material variabilities or design margins
- Overpressurization can be caused by:
  - Excess propellant surface area
  - Nozzle area reduction/blockage
  - Change in propellant combustion properties
- Testing and analysis quickly reduced the cause to excess surface area
  - Manufacturing techniques were modified
  - Rocket motor burn was consistent

Performance Predictions – Pressure vs. Time

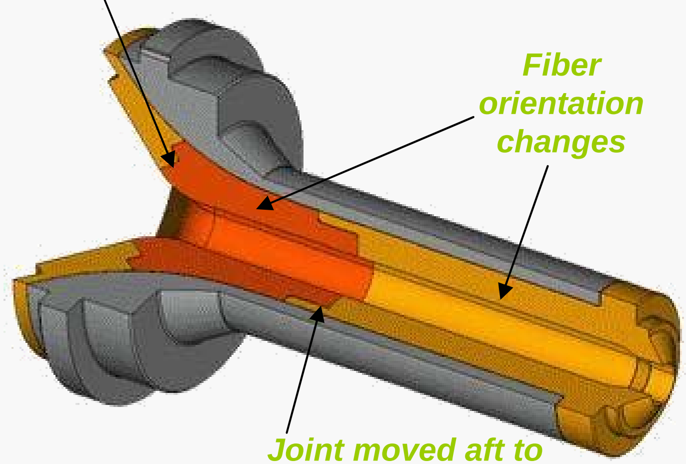


Nozzle Improved to Provide Thermal Margin



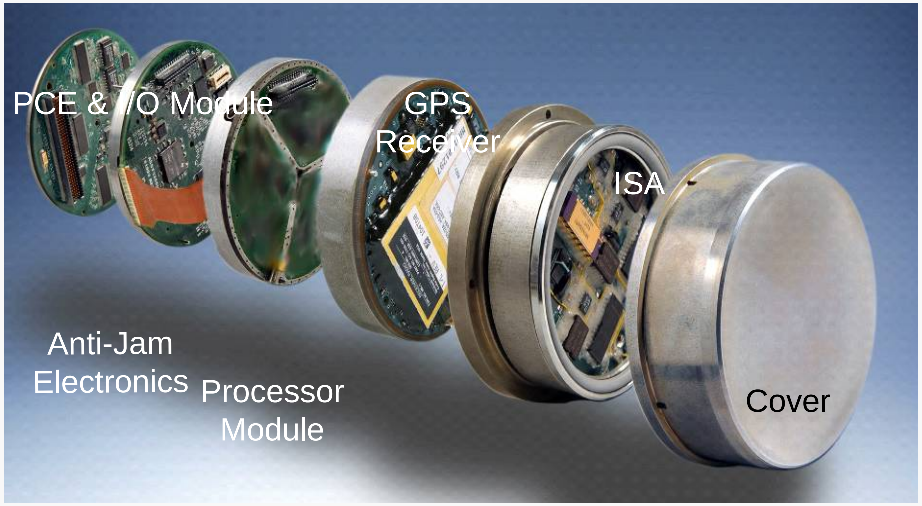
Nozzle Insulation Improvements

- Conducted detailed review with NSWCDD on 01 Jun 06
  - Agreement on changes & test plan
  - Team agreed on a material fiber orientation changes to approach and blast tube to resist erosion
- Approach thickness changed to better resist charring / heat
- Spinning static fire tests validated changes
  - Erosion analysis added confidence



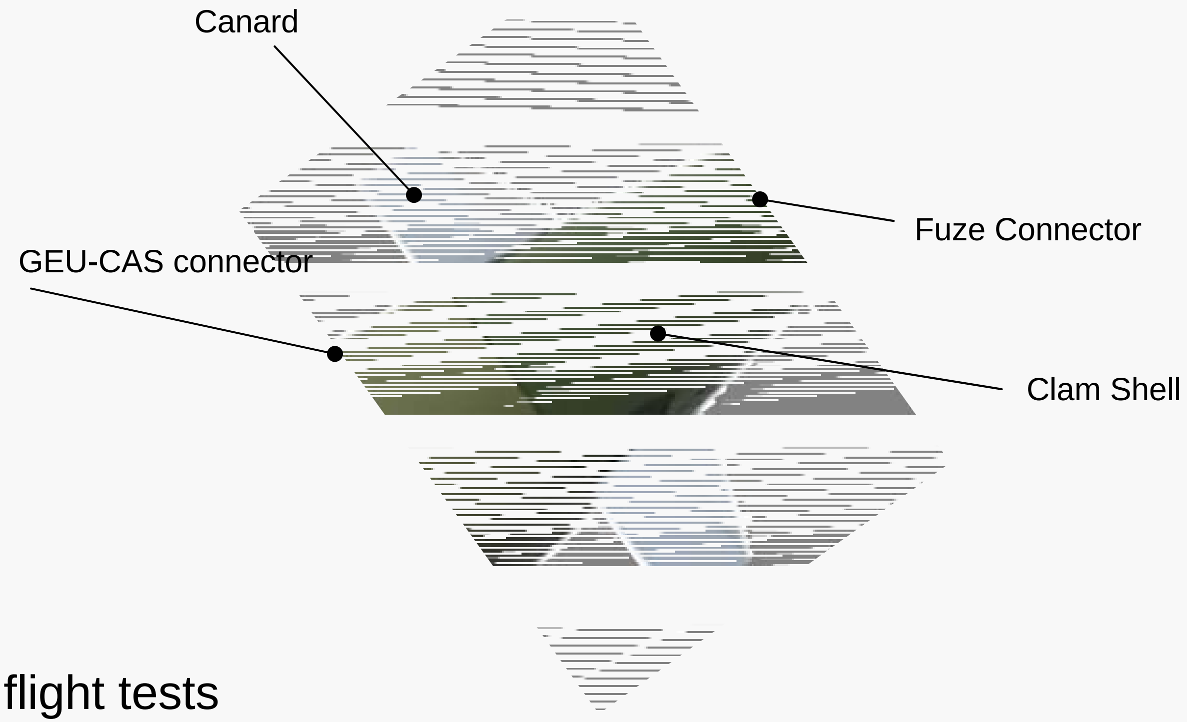
Low Cost Guidance Electronic Unit (LCGEU)

- Developed by Draper Laboratory
  - Navy funded
  - Originally developed as risk reduction for ERGM
  - Rockwell-Collins SAASM GPS receiver
    - Direct-Y acquisition
- Survives and operates in gun environments > 10,000 g's
- Deep Integration GPS anti-jam algorithms
  - Allows inexpensive commercial MEMS gyros and accels
- Proven success and robustness in laboratory and live fire tests
  - Multiple platforms
- Guidance control laws are robust to system errors



BTERM II Low Cost Guidance Electronics Unit is a Mature Demonstrated Design

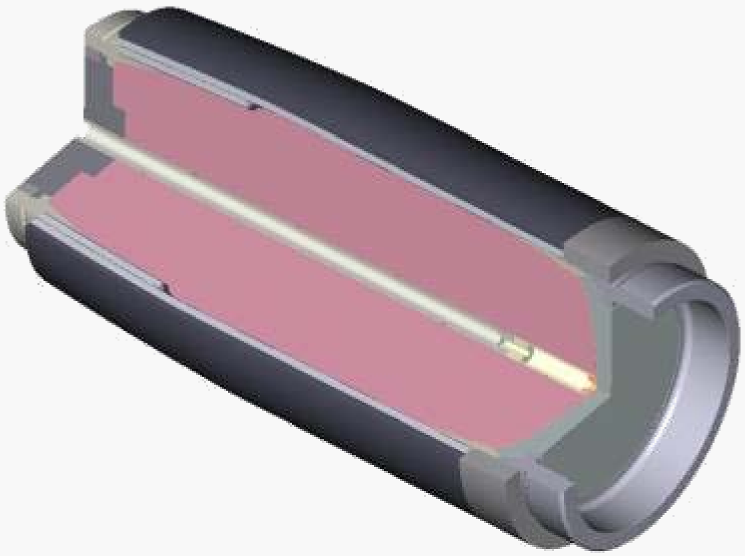
CAS Configuration and Performance History



- Improved design for interconnect to GS and Fuze sections
- Optional Al or Steel clam shells
- Proven battery pack in numerous flight tests
- Current design proven in flight tests
- Robustness demonstrated in GFT301-1C
- Added current limit to protect battery from over-current

Warhead Configuration and Performance History

- Case showed excellent results in crush test
- System effectiveness, based on results of first warhead arena test, exceeded system performance requirements
- Recovered fragments demonstrated integrity with respect to explosive launch



Warhead Components	Description	Weight
Composite	**Graphite**	***0.9 lbm***
Explosive	***PBXN-9***	
Booster Charge	***PBXN-11***	***0.05 lbm***
Initiator	**RP-80**	***N/A***

Guided Flight Results

- GUFT-1
  - February 2006
  - **G**uided **U**nboosted **F**light **T**est
  - 8.7nmi@ Yuma Proving Grounds-> 7.3nmi sea level
  - 5 foot miss distance from target

- GFT-301
  - September 2008
  - **G**uided **F**light **T**est
  - 54nmi@ White Sands Missile Range-> 49nmi sea level
  - 15 foot miss distance from target

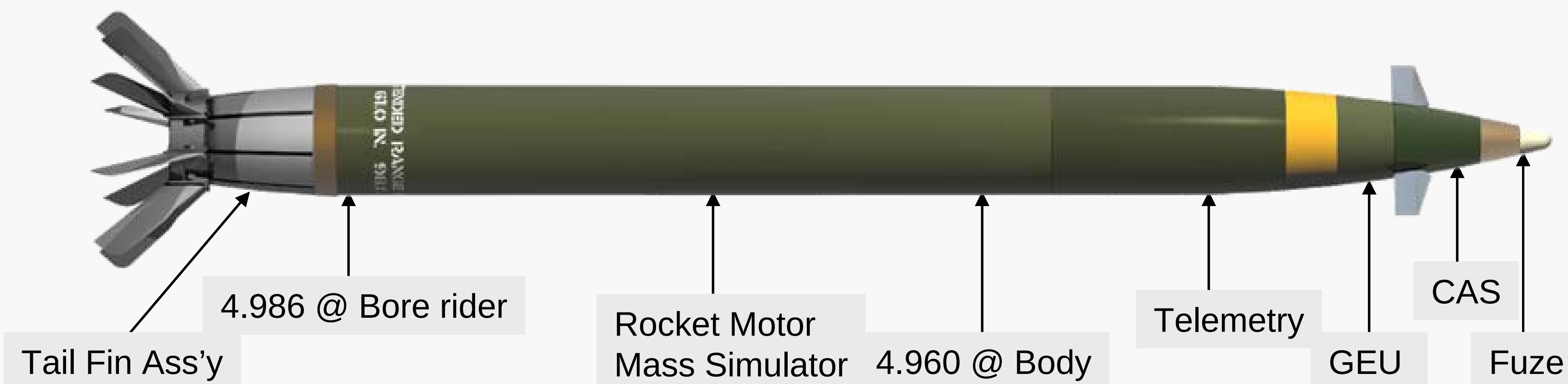
GUFT-1 Mission Overview

Test:
- Location: Yuma Proving Ground (YPG)
- Test dates – 08 February 2006

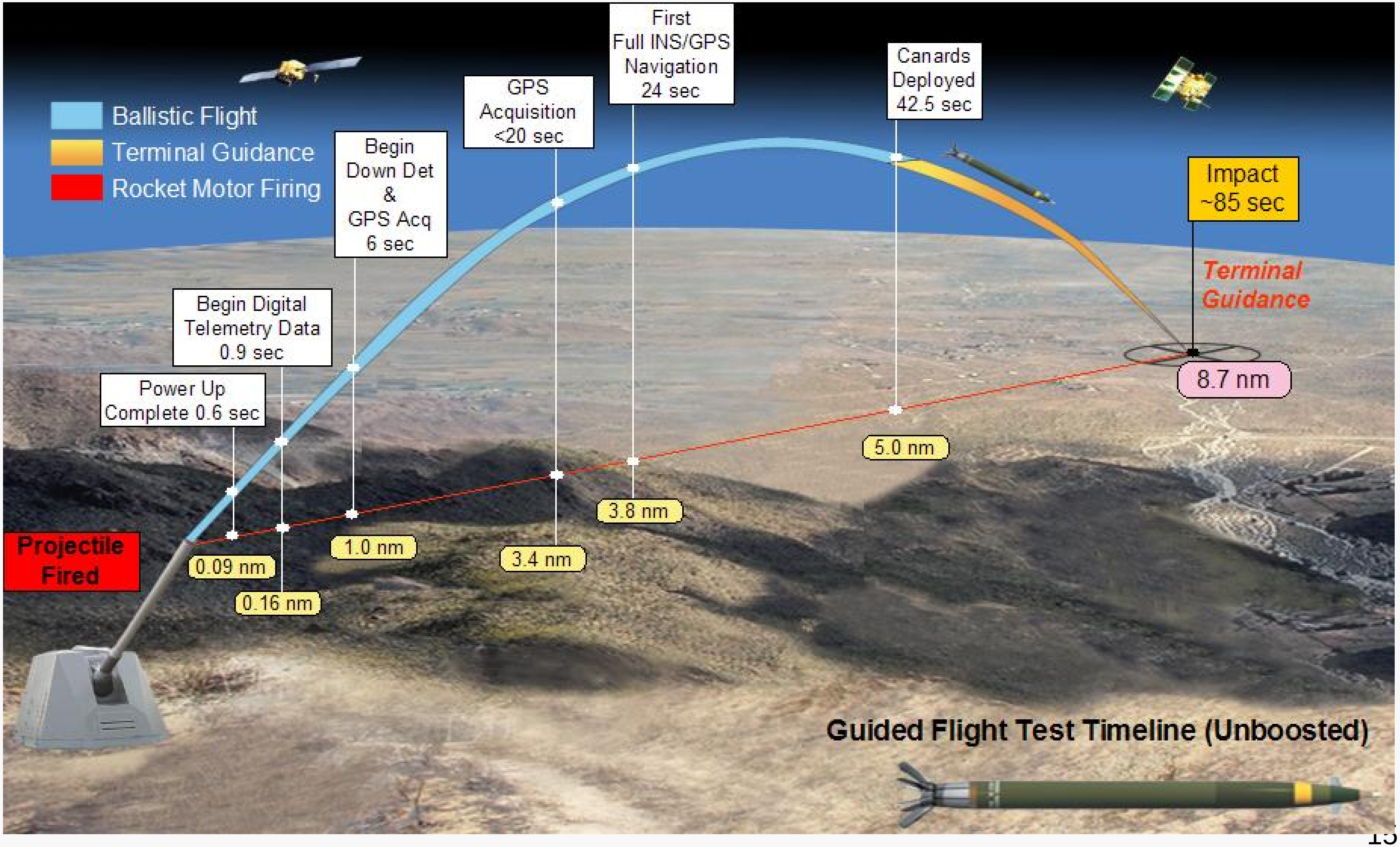
Test Conditions:
- 5"/62 Caliber Gun (S/N 17499)
- NACO Propellant Charges
- Muzzle Velocity = 2,170 ft/sec
- Expected Launch Accel = 7,200 G
- GUFT-1/ODT QE = 60.5°

Test Configurations:
- 3 Baseline Obturated TCD Slugs
- 1 Guided, Unboosted Flight Test (GUFT-1)

Instrumentation:
- 3 M11 and 2 Piezoelectric Pressure Sensors within Propelling Charges
- Barrel Pressure Data
- Camera Coverage at Gun and Target
- Trajectory and Muzzle Radar
- Telemetry for GUFT-1



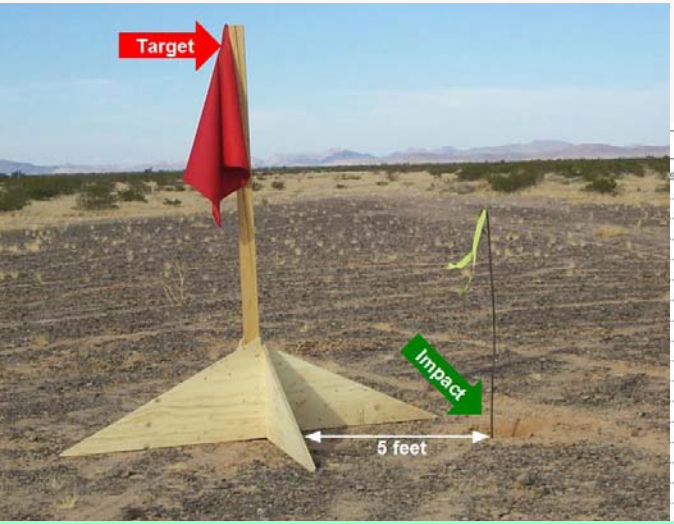
February 8, 2006 Guided Unboosted Results



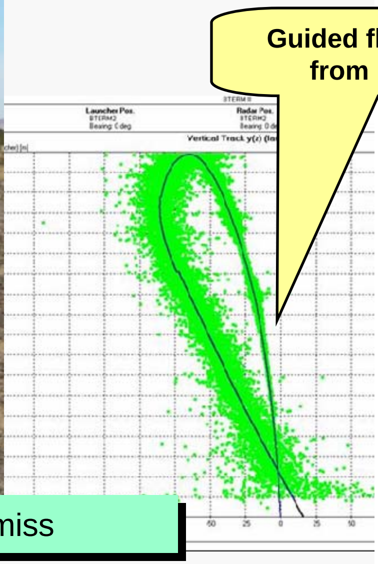
GUFT-1 Mission Objective Results

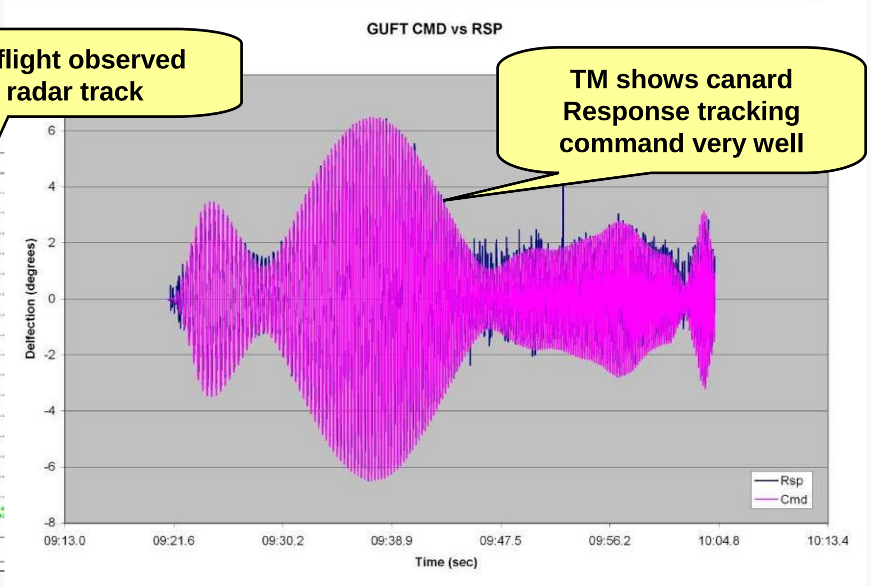
- New mag based down determination successful
- GPS acquisition successful
- Canard deployment successful
- Canard control successful
- **Hit the TARGET!**

Test Objective	Criteria	Results
Evaluate short range GNC algorithms	**Successful acquisition of telemetry and radar data**	Passed
Demonstrate CAS performance with COTS actuator	**COTS actuator demonstrates the ability to control the flight trajectory using commands issued by the GEU**	Passed



1.5m impact instead of 185m ballistic miss

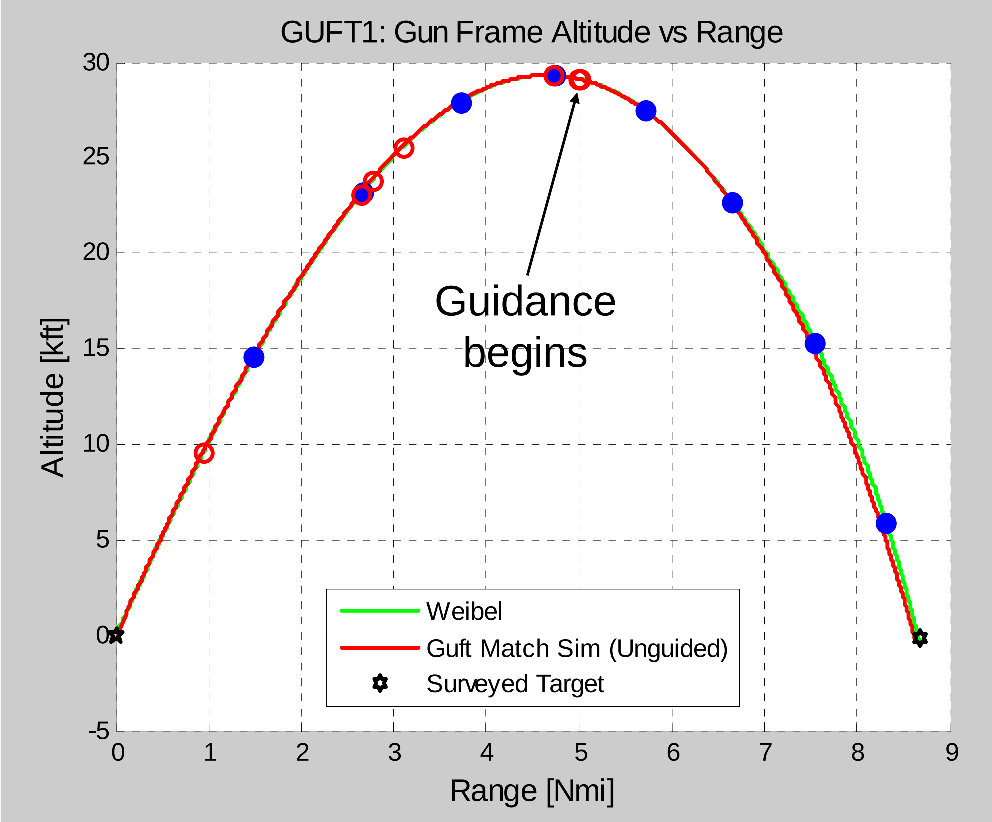




GUFT 1 – Flight Test Results

GNC

- GPS
  - Acq at 20 sec and held throughout
- Improved down determination enables early navigation
- GEU sensors survived launch and performed as expected
- Guidance/control commands issued starting at 42 sec
  - CAS response good
  - 5 ft miss at target
- Impact at 86 sec at 8.7 nm



GFT-301 Mission Overview

Test:

- Location: White Sands Missile Range (WSMR) – Site L531
- Test Date – 29 Sep 2008

Test Conditions:

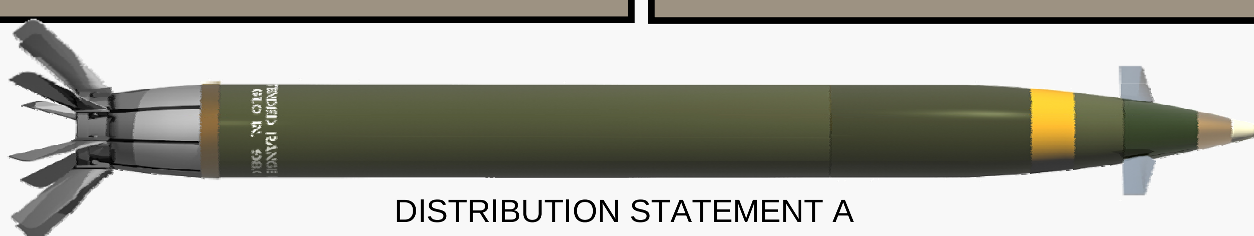
- 5”/62 Caliber Gun (S/N 17499)
- NACO Propellant Charges
- Muzzle Velocity = 2170 ft/sec
- Expected Launch Accel = 7200g
- Projectiles QE ~ 59.3°
- GFT-301 long range ~ 54 nmi

Test Configurations:

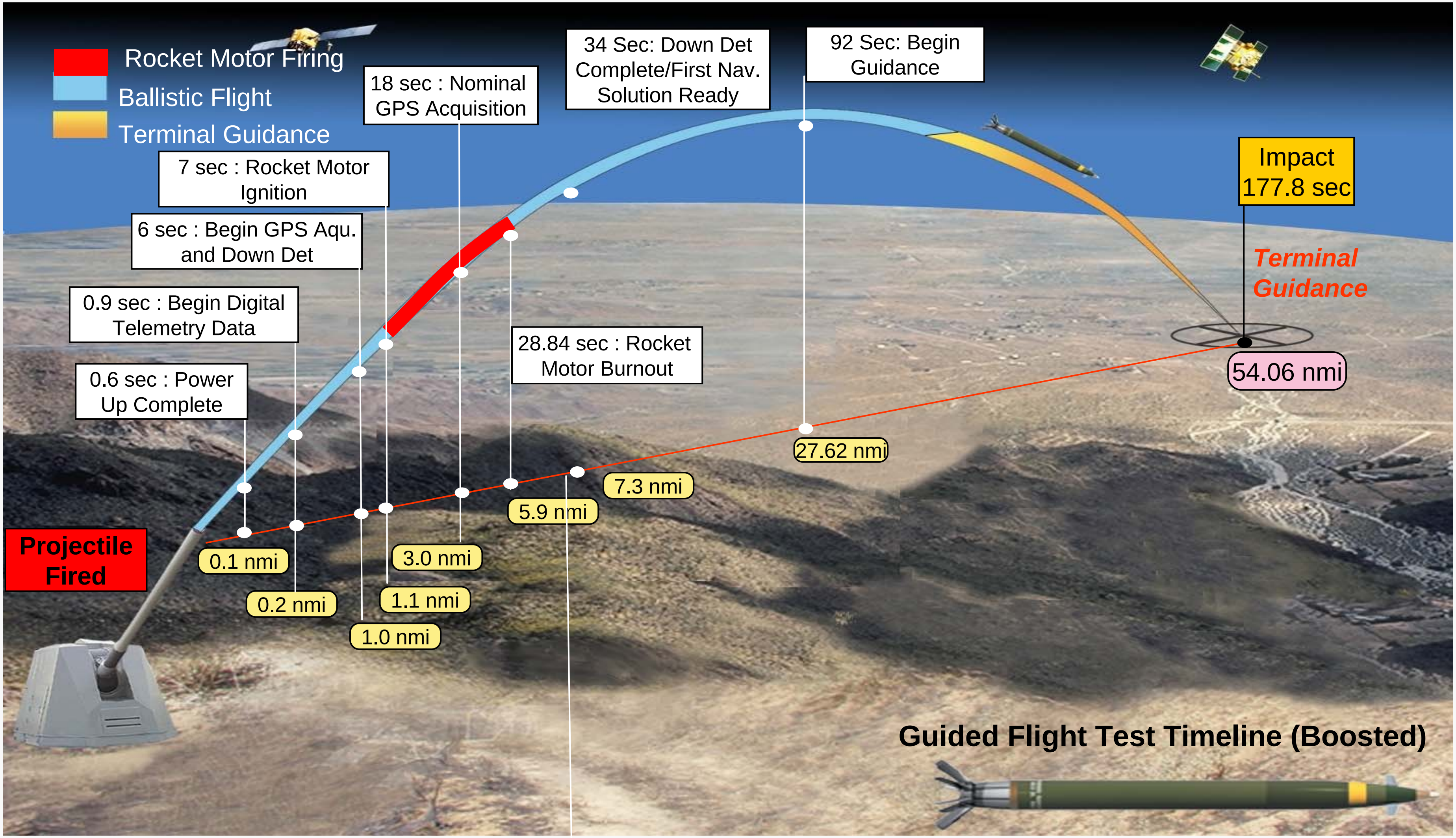
- 2 TCD Slugs + 1 backup
- 2 GFT-3 Guided, Boosted Flight Test
- 1 EET-3 Guided, Boosted Flight Test

Instrumentation:

- 3 M11 and 2 Piezoelectric Pressure Sensors within Propelling Charges
- Barrel Pressure Data
- Camera Coverage @ Gun & Targets
- Trajectory & Muzzle Radar
- ATK Telemetry



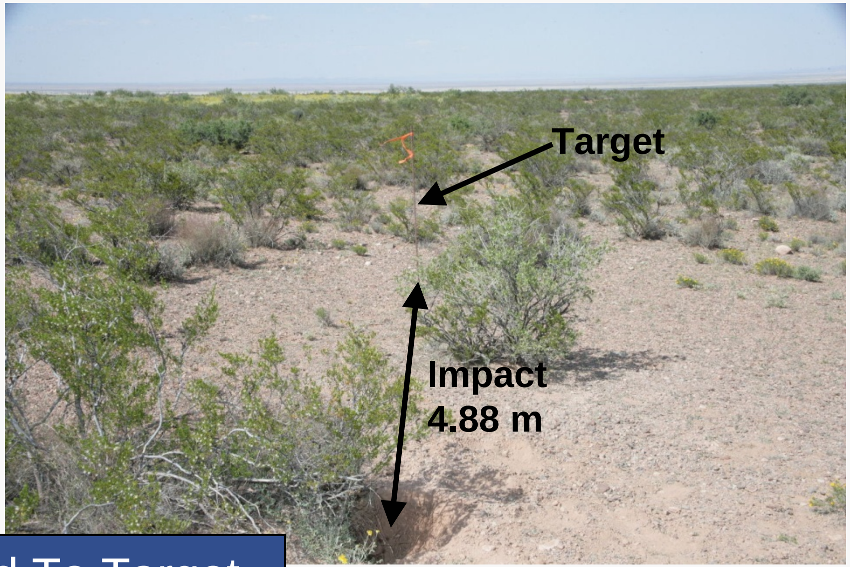
GFT-301 Flight Profile



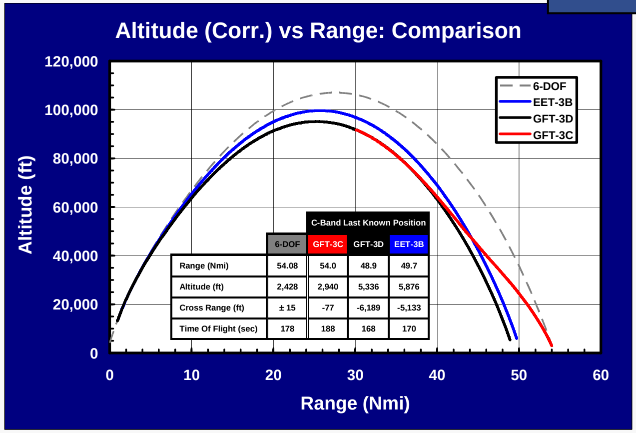
Recent BTERM Success

Sept 2008 test success

- **Achieved 54 nmi range**
  - Full duration rocket motor burn
- **4.9 m miss distance**
  - Acquired 10 satellites in direct Y
  - Corrected 5 nmi of range error
  - Corrected 0.9 nmi of cross range error

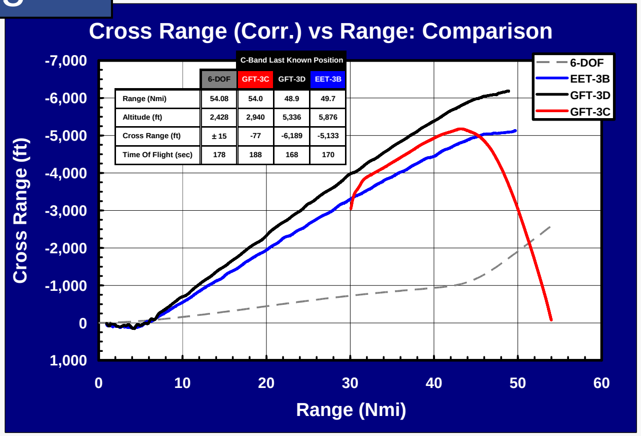


GFT-3C Guided To Target



	6-DOF	GFT-3C	GFT-3D	EET-3B
		C-Band Last Known Position		
Range (Nmi)	54.08	54.0	48.9	49.7
Altitude (ft)	2,428	2,940	5,336	5,876
Cross Range (ft)	± 15	-77	-6,189	-5,133
Time Of Flight (sec)	178	188	168	170

All Three Test Projectiles On Very Similar Trajectories



	6-DOF	GFT-3C	GFT-3D	EET-3B
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Altitude (ft)	2,428	2,940	5,336	5,876
Cross Range (ft)	± 15	-77	-6,189	-5,133
Time Of Flight (sec)	178	188	168	170

Recent Success Validates 5" Gun Solution for NSFS

Program Accomplishments

- Demonstrated short and long range guidance accuracy
  - 8-nmi guided flight test within approximately 5-feet of the intended aim-point
  - 54-nmi guided flight test within approximately 15 feet of the intended aim point
  - Low Cost Guidance Electronics Unit (LCGEU) continues to demonstrate robust performance meeting all requirements
  - 6-DOF simulation accurately predicts actual guidance performance
  - CAS (w/COTS components) provides sufficient control authority to meet guidance accuracy requirements
  - Tail fin deployment and locking
  - Electronic ISD demonstrated

Program Accomplishments

- Demonstrated subsystems
  - Guidance, navigation and control subsystem and algorithms
  - Composite blast fragment warhead
  - Single Axis CAS including the COTS actuator
  - Electronic Ignition Safety Device
  - Reliable rocket motor performance

- Demonstrated lethality of warhead
  - Arena tests at NSWC-DD demonstrated lethality meets or exceeds requirements against the ERM target set
  - Actual performance better than simulation/model
  - Crush test demonstrated strength exceeds requirement for BTERM launch environment of ~7500-g

- Demonstrated the data communications interface (DCI)
  - Benchtop tests with ERM setter

US ARMY RDECOM

U.S. Army Research, Development and Engineering Command

Trajectory Matching Procedure/Practice for a Guided Projectile using MATLAB/Simulink

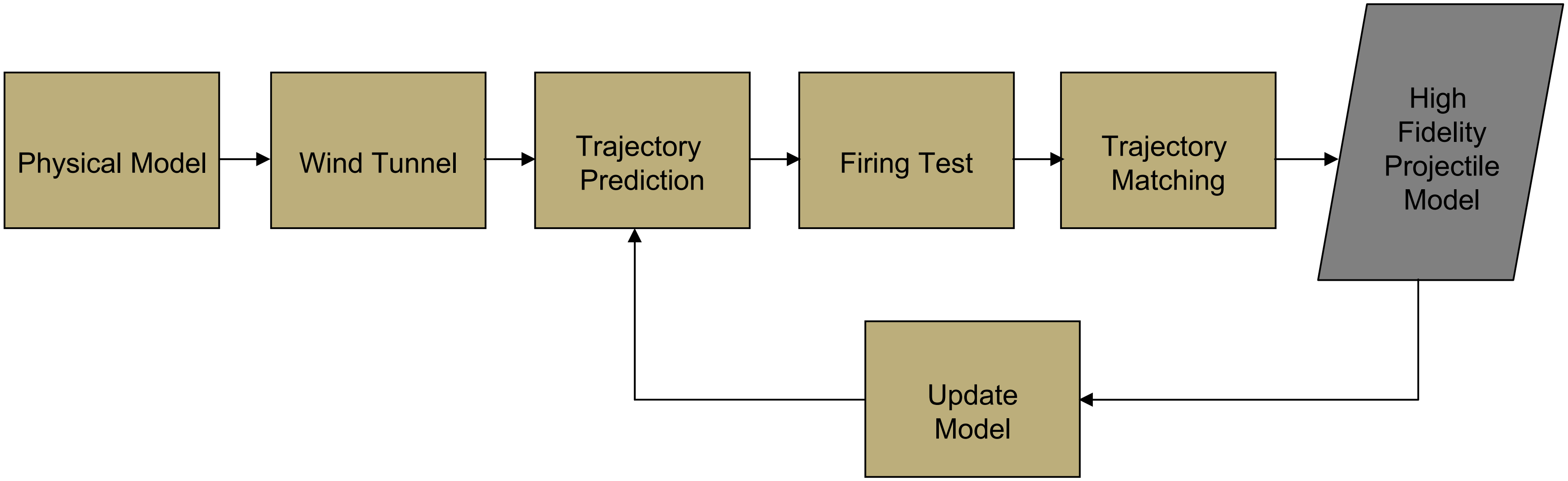
TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Yin Chen (x-4945)
Thomas Recchia (x-8853)
AEROBALLISTICS DIVISION

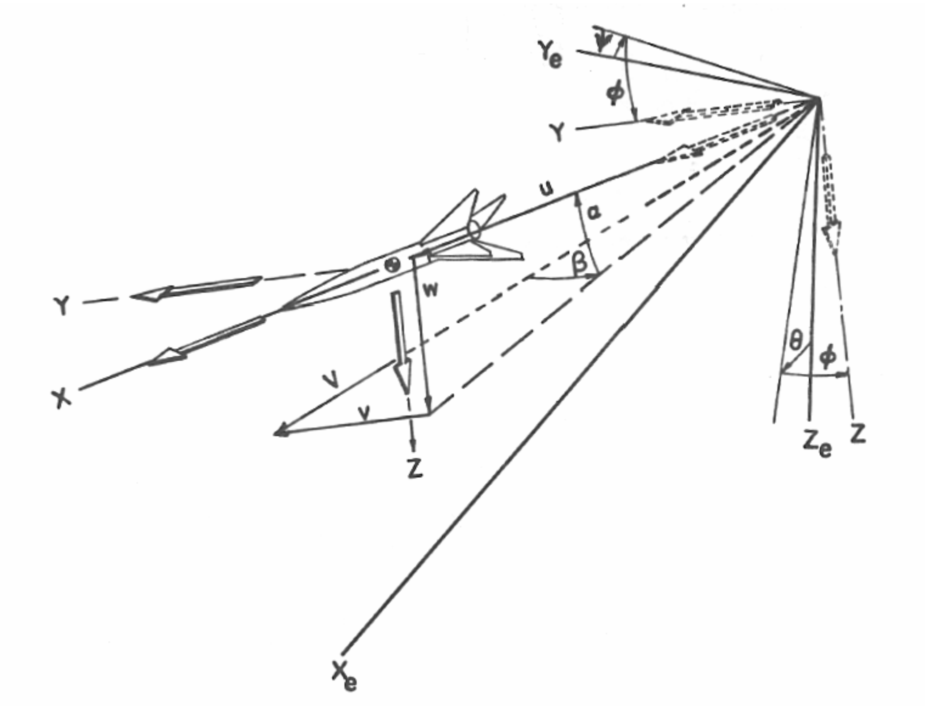
October 21-22, 2008

Process Overview

- Objective: to Obtain a High Fidelity Simulation of Guided Munitions.
  - Statistical Testing is too expensive
  - Predict Performance
  - Conduct Root Cause Analysis

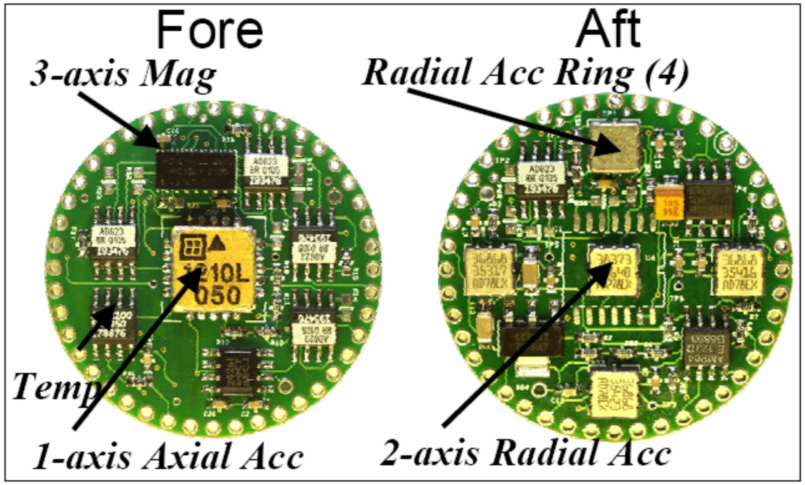


- Basic Forces and Moments Acting on the Body
  - Aerodynamic Forces
  - Aerodynamic Moments
  - Gravity
- Effects due to External Conditions
  - Wind
  - Pressure/Altitude
  - Temperature
  - Location
- Types of Projectiles
  - Spinners
  - Finners



Background: Sensors & Controls

- Sensors
  - Measure Location, Speed, Orientation
    - IMU
      - Accelerometers
      - Rate Gyros
    - GPS
    - Radar
    - Inclinometers
    - Solar Sondes
    - Magnetometers

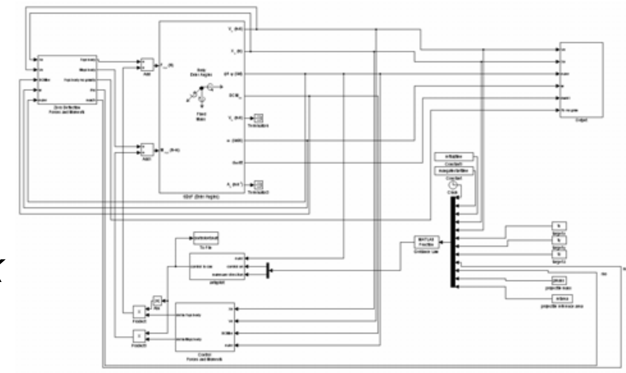


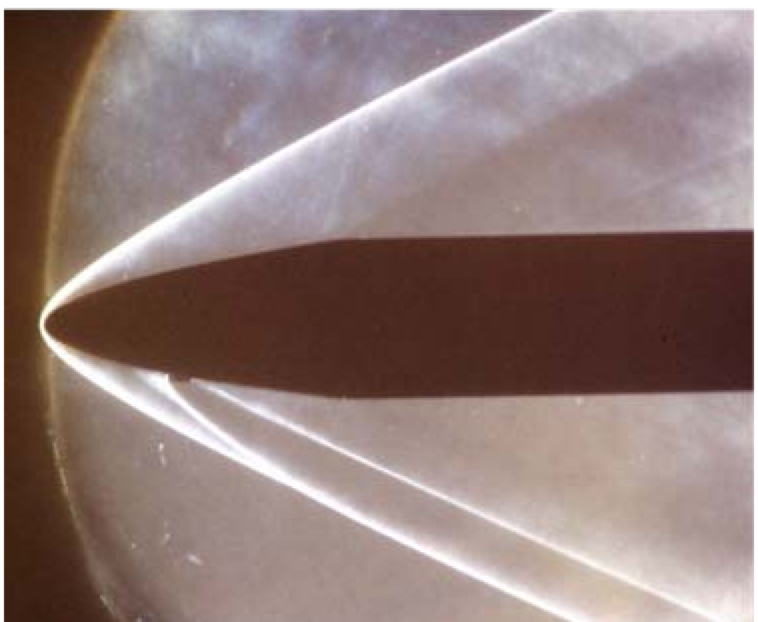
Example: ARL Sensor Suite Board

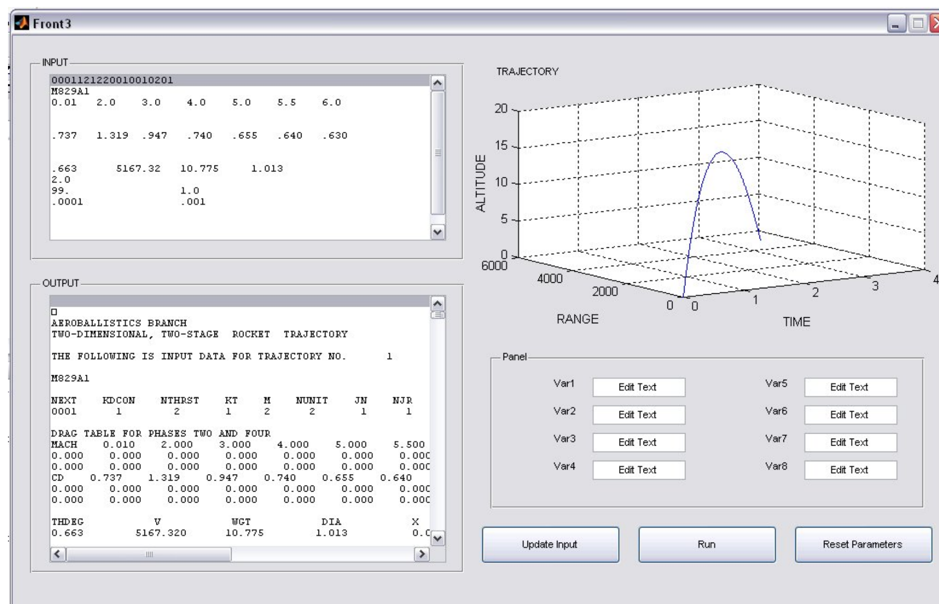
- Control Mechanisms
  - Correct the Projectile's Path to Guide to a Goal
    - Canards/Fins
    - Rocket Thrusters
    - Heating/Cooling of Ambient Air
    - Ventilation Control through Projectile Body
    - Projectile Skin Morphology (Flexures)
    - Microactuators

Pre-Test Modeling

- Physical Models
  - CAD (Pro Engineer)
  - PRODAS
  - Missile DATCOM
  - CFD
  - Wind Tunnel Modeling
- Trajectory Simulations
  - Aero1
  - Traj
  - Tela
  - *MATLAB/Simulink*







Pre-test Modeling in Practice

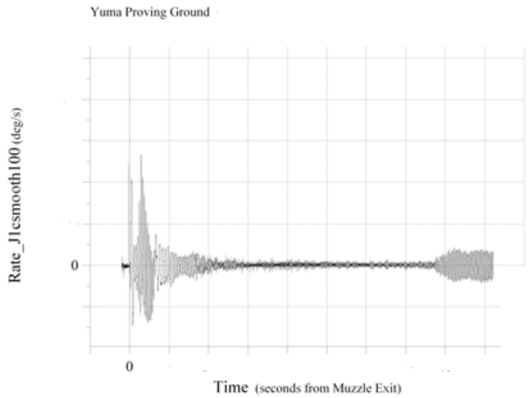
- Wind Tunnel Produced:
  - Static Coefficients
    - C_x
    - $C_{N\alpha}$
    - $C_{m\alpha}$
    - C_{lo}
  - Dynamic Derivatives
    - C_{lp}
    - $C_{m\dot{\alpha}} + C_{mq}$
- MATLAB 6-DOF
  - Wind Tunnel coefficients were used to create a trajectory

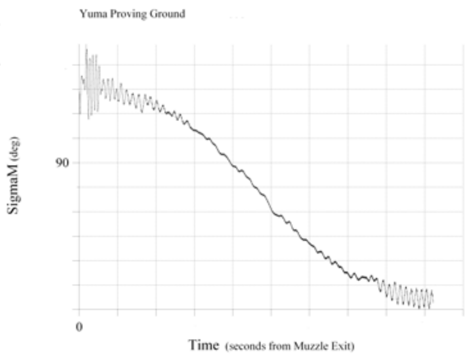
- CFD Produced:
  - Static Coefficients
    - C_x
    - $C_{N\alpha}$
    - $C_{m\alpha}$
    - C_{lo}
  - Dynamic Derivatives
    - $C_{np\alpha}$
    - C_{lp}
    - $C_{m\dot{\alpha}} + C_{mq}$

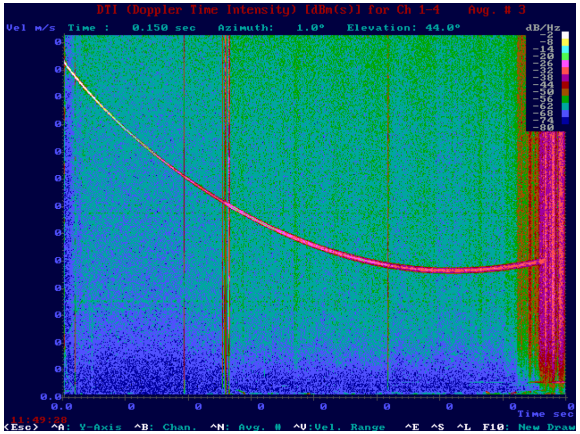
Data Acquisition/Reduction

- Wind Tunnel Test
  - Entire Range of Mach Numbers
  - Various Angles of Attack
  - Compared with CFD and aero prediction code results

- Firing Test
  - Acquires “Real” Data
    - Mass Properties
    - Pressure Gauge Data
    - Muzzle Velocity (Weibel Radar)
    - Tracking (Weibel Radar, MTS Radar)
    - ARL Sensor Package
      - Rate Sensors Data
      - Magnetometer Data
      - Accelerometers
      - Solar Sondes
    - Exact GPS Location of Gun and Impact
    - Met Data for Time of Fire







Trajectory Matching

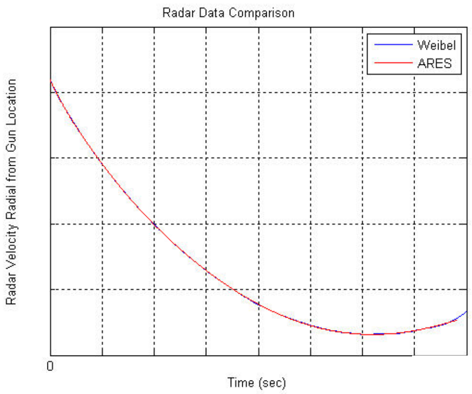
- Initial conditions are adjusted as closely as possible to the day of fire.
  - Met Data
  - Mass Properties
  - Initial Velocity

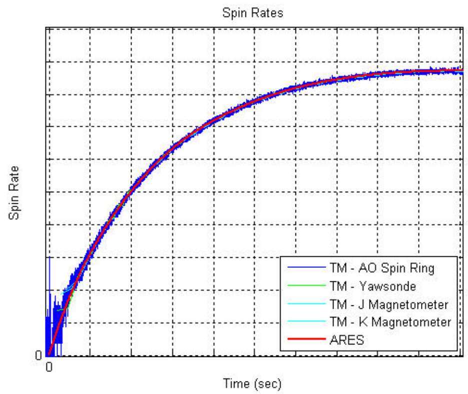
- Simulink 6DOF is run to compare the output of the simulation with the actual performance of the round

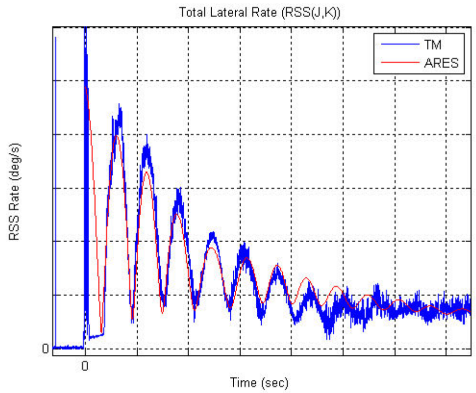
- Form Factors are applied by hand to adjust the performance of the simulation to coincide with the actual trajectory
  - Form Factors are coefficients applied to the variables governing the projectile's performance.
  - Adjustment starts with the earliest point in the trajectory and moves forward with time.
  - Adjustment cycles through:
    - Position/Velocity Matching
    - Magnetometer Matching
    - Spin Rate Matching

Data Reduction in Practice

- Reconcile CFD Outputs with Wind Tunnel Test Results
  - Modify Variables if Necessary
  - Chose One Set or Average Both if Numbers are Close
- Firing Test Data
  - Corrected Acceleration and Rates Loaded into MATLAB
  - Centered Smoothing Algorithm used to Remove Noise
  - Interpolate Different Sets of Data into Same Time Step
  - Root Sum Squared Accelerometer and Rate Data
  - The RSS is Examined to find Maneuver Times
  - Met Data is Loaded into the Simulation

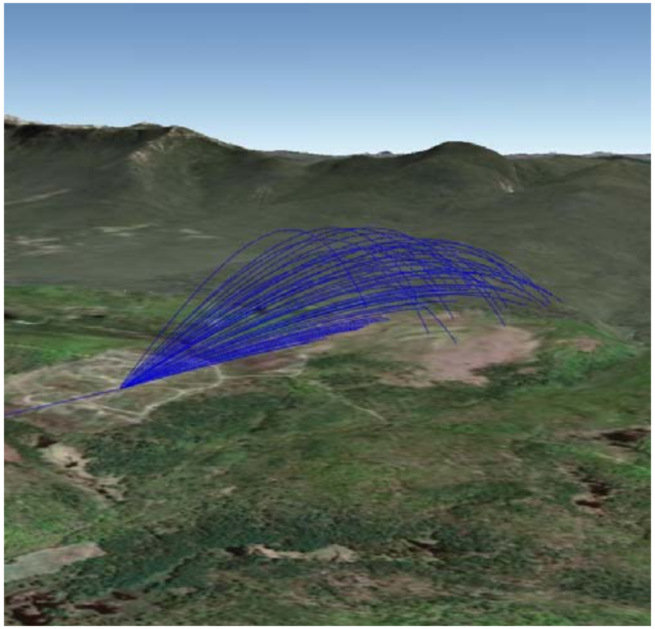






Benefits of a High Fidelity Simulation of Guided Munitions

- Immediate
  - Decrease design turn-around time
  - Higher fidelity to actual round in progress
  - Better prediction of subsequent firing tests
  - Gauges difference to goal
  - Power/effectiveness of unit maneuver
  - Number of maneuvers required to reach target
  - Suggestions for design improvement



- Future
  - Safety Danger Zone analysis
  - Root cause analysis for discrepancies
  - Affirmation of design capabilities
  - Decrease number of rounds fired to generate firing tables
  - Assist users in developing doctrine

Conclusions

- MATLAB/Simulink has been used to obtain a high fidelity simulation of a guided munition
  - Model has successfully predicted performance
    - Aiming
    - SDZ verification
  - Model was used to reproduce unforeseen projectile motion
  - Implemented Monte Carlo analysis to assist GNC development

- This analysis can easily be applied to future programs
  - MATLAB/Simulink model is easy to modify
  - Can support unique configurations/conditions

- For more information, contact the AEROBALLISTICS DIVISION, METC

QUESTIONS?

Modeling and Simulation Advances in Large Caliber Muzzle Brake Development

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

NDIA Gun & Missile Systems Conference & Exhibition

April 6-9, 2009, Kansas City, MO

Daniel L. Cler
Robert A. Carson
Mark A. Doxbeck
Jeffrey M. Greer
Mark D. Witherell

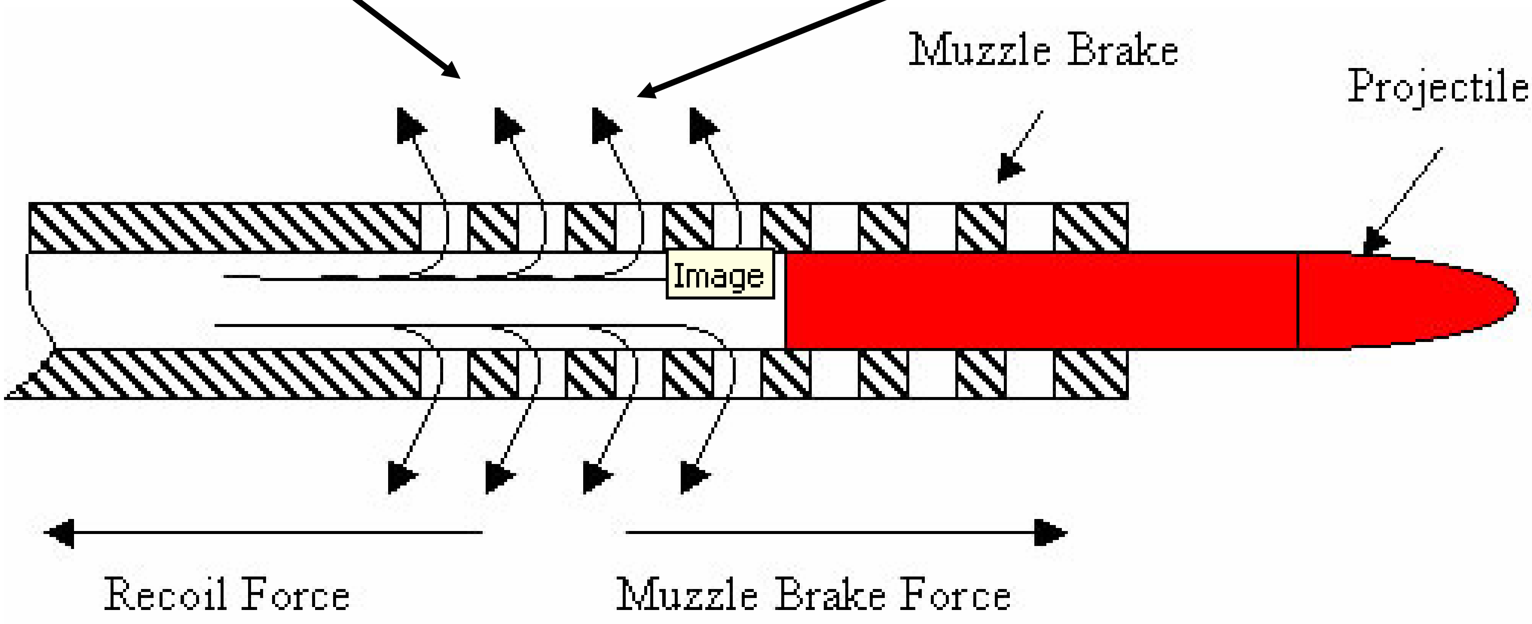
Outline

- Basic Muzzle Brake Design Principles
- Impulse Reduction Modeling
- CFD Based Blast Modeling
- Empirical Blast Modeling
- One-Way Structural-Thermal Modeling
- Two-Way Fluid-Structure Modeling

Muzzle Brake Design Principles

Reduced gun impulse

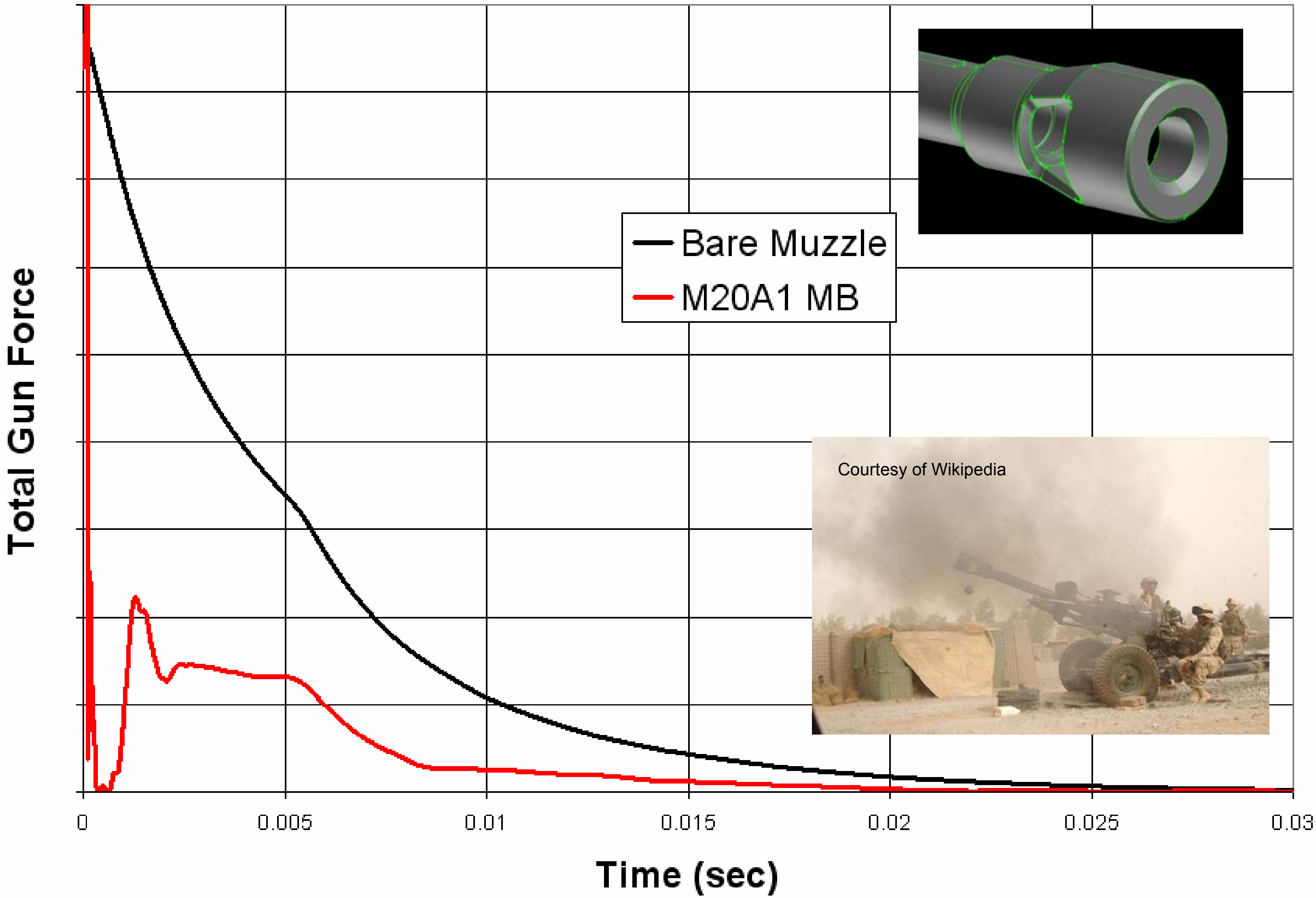
Minimize blast effects



Minimize gun weight

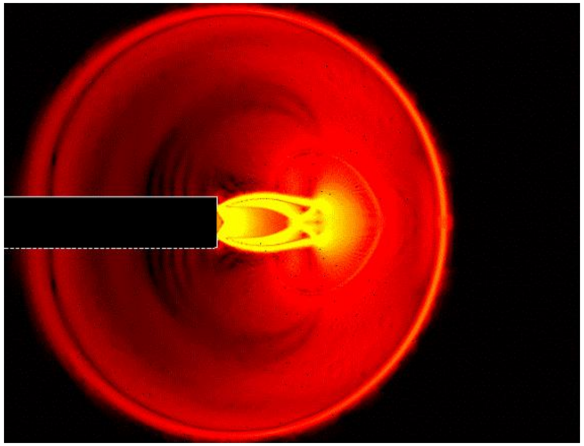
Minimize flash

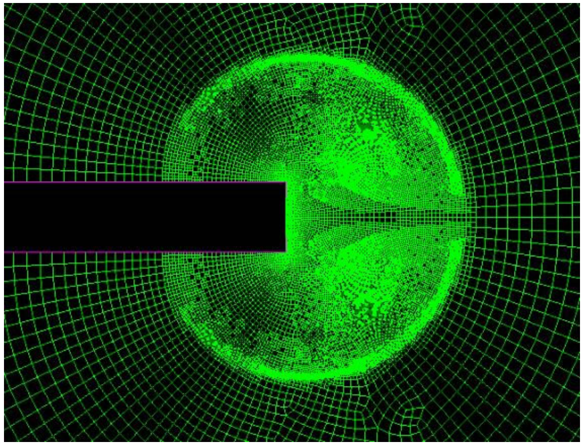
M119 - M20A1 Baseline Impulse Study
Unsteady 3-D CFD Simulation Results



CFD Based Blast Modeling

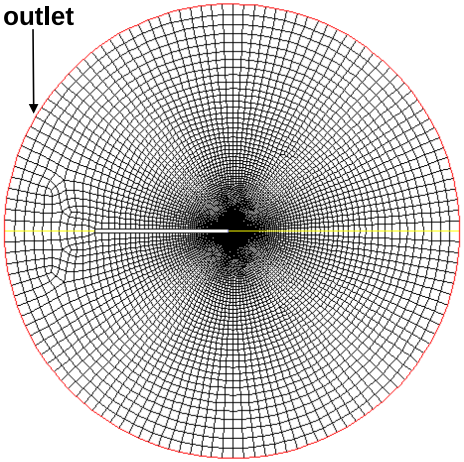
- **Blast - Moving Shock Wave**
  - **Propagates at Faster than Speed of Sound**
  - **Very Fine Structures (0.5 mm thick)**
  - **Very High Pressures (7,000 – 15,000 psi at muzzle)**
- **CFD Requirements**
  - **Shock Wave is a Discontinuity in Flow Field**
  - **Requires**
    - **Very Fine Grid**
    - **High-Order Spatial Resolution**
    - **Very Large 3-D Flow Domains**
  - **Fixed Grids are Not Feasible for 3-D Gun Simulation**
  - **Higher Order Solvers Typically Not Stable at Gun Pressures**
  - **Dynamic Grid Adaption is Only Realistic Option**
  - **Highly Specialized Codes is a Second Option**
- **Dynamic Grid Adaption**
  - Refine and Coarsen Mesh as Blast Wave Propagates Through Flow Domain
  - Based on Flow Field Gradients and Properties
  - Solution Based Automatic Adaption



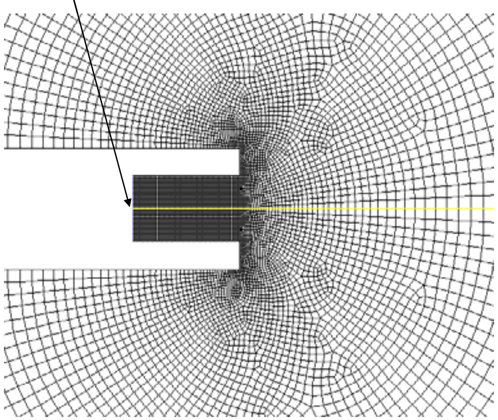


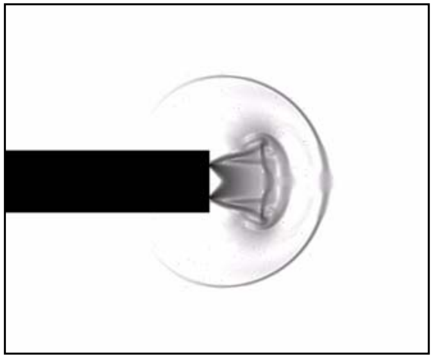
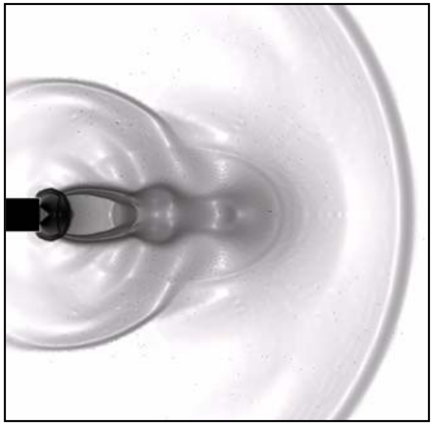
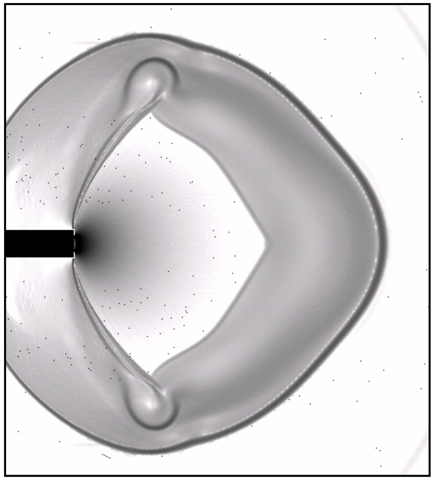
CFD Blast Analysis – Fluent
7.62 NATO G3 with DM41 Round

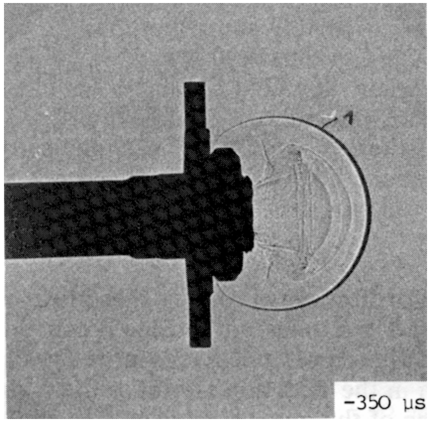
Pressure outlet

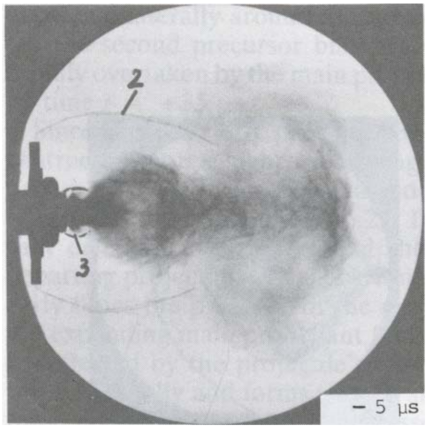


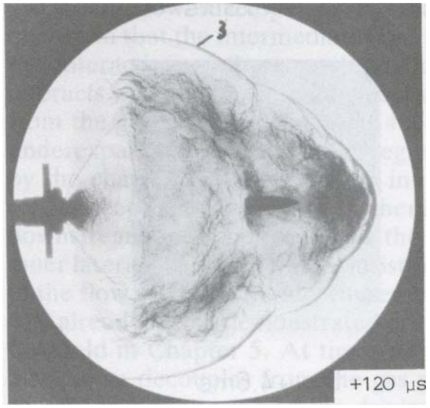
Pressure-inlet



	1st Pre-Cursor	2nd Pre-Cursor	Main blast wave
			
FLUENT:	t = -350 μsec	t = -5 μsec	t = +120 μsec







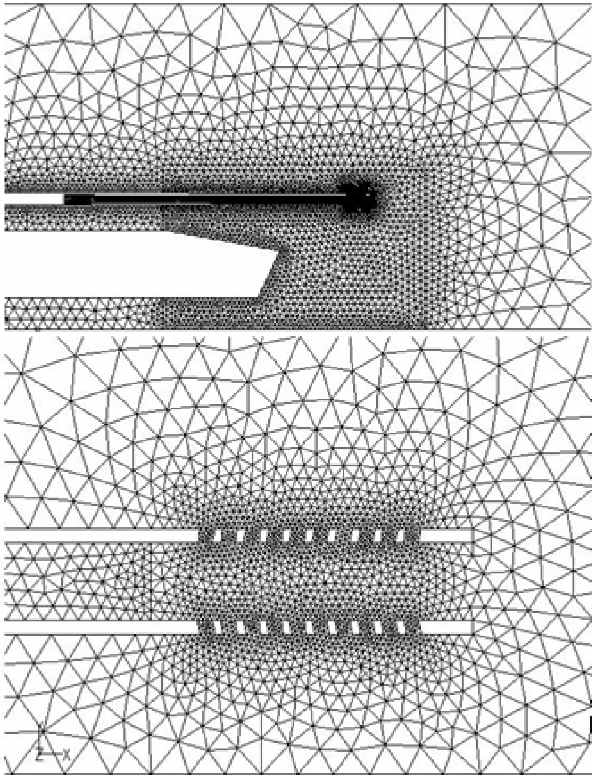
Experiment

Ref: Gun Muzzle Blast and Flash, Progress in Astronautics and Aeronautics, Vol. 139; Klingenberg, Gunter, Heimerl, Joseph M., Seebass, A. Richard Editor-in-Chief, AIAA

BWIP
Mesh and Solution-based Adaption Parameter

Solution-based Blast Wave Identification Parameter (BWIP)

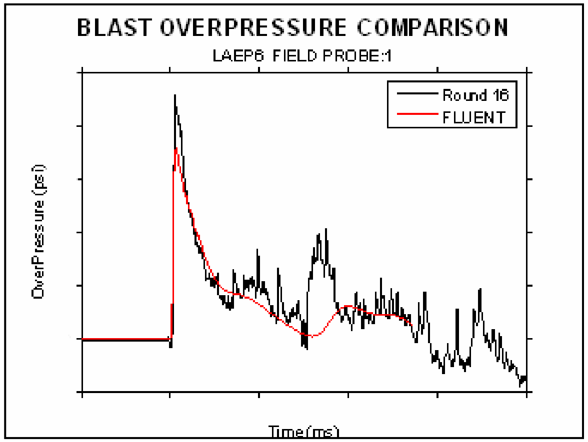
- ANSYS-Fluent CFD Solver
- Add-on to Improve Adaption
- Find Shock Location
  - Mach Number Near 1
  - Large Pressure Gradient
- Control Adaption
  - Better Coarsening
  - Better Refinement
- Reduce Total Cell Count
- Reduce Solution Time
- Improve Quality With Finer Resolution

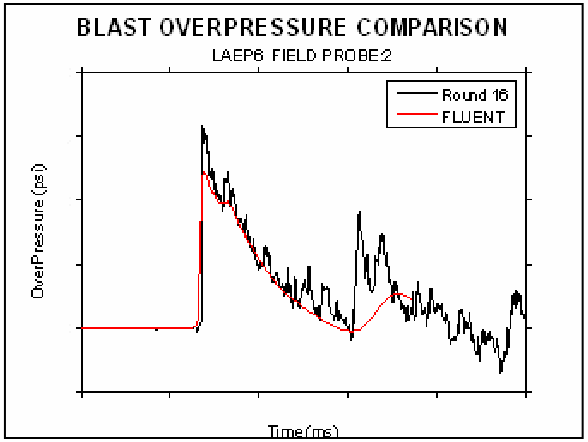


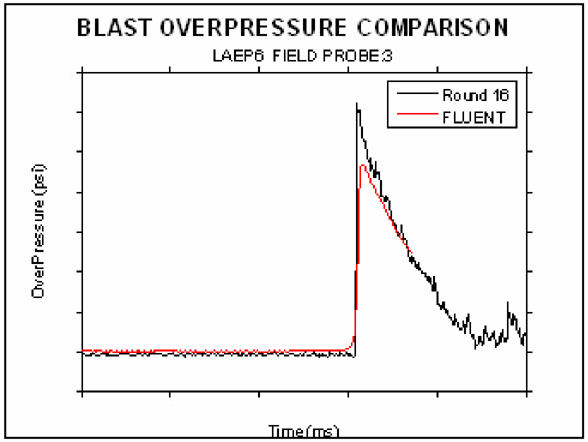
XM-360 Gun on
FCS MCS Chassis

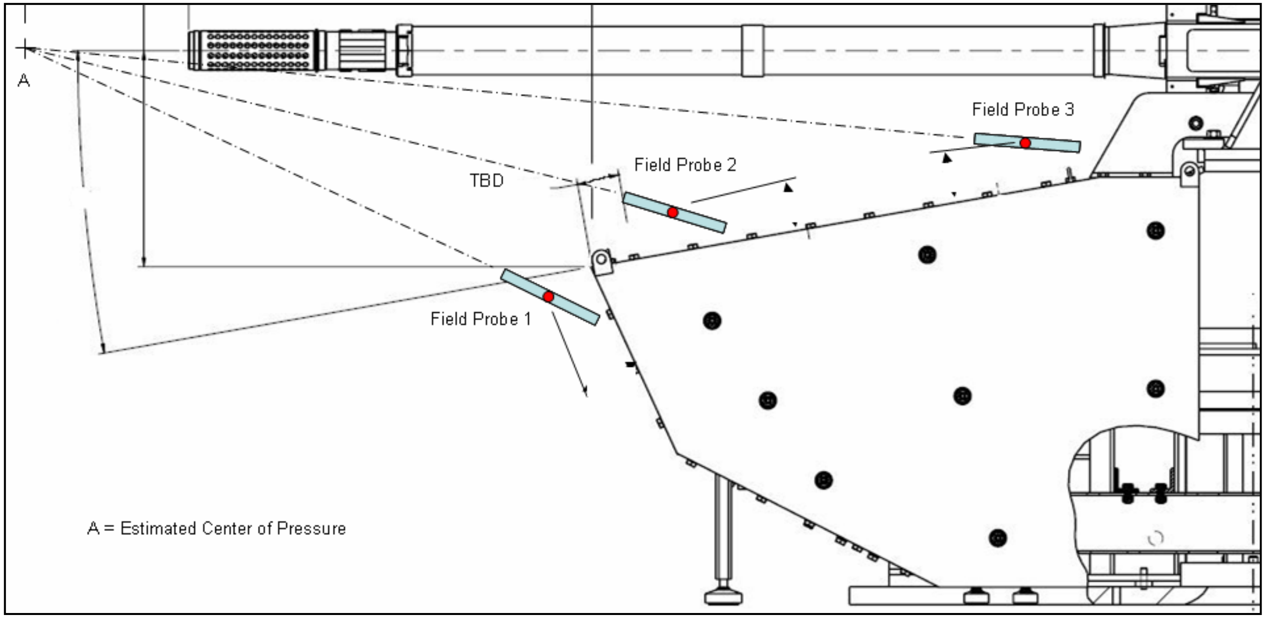
BWIP Validation

Overpressure for XM-360 on FCS MCS Chassis

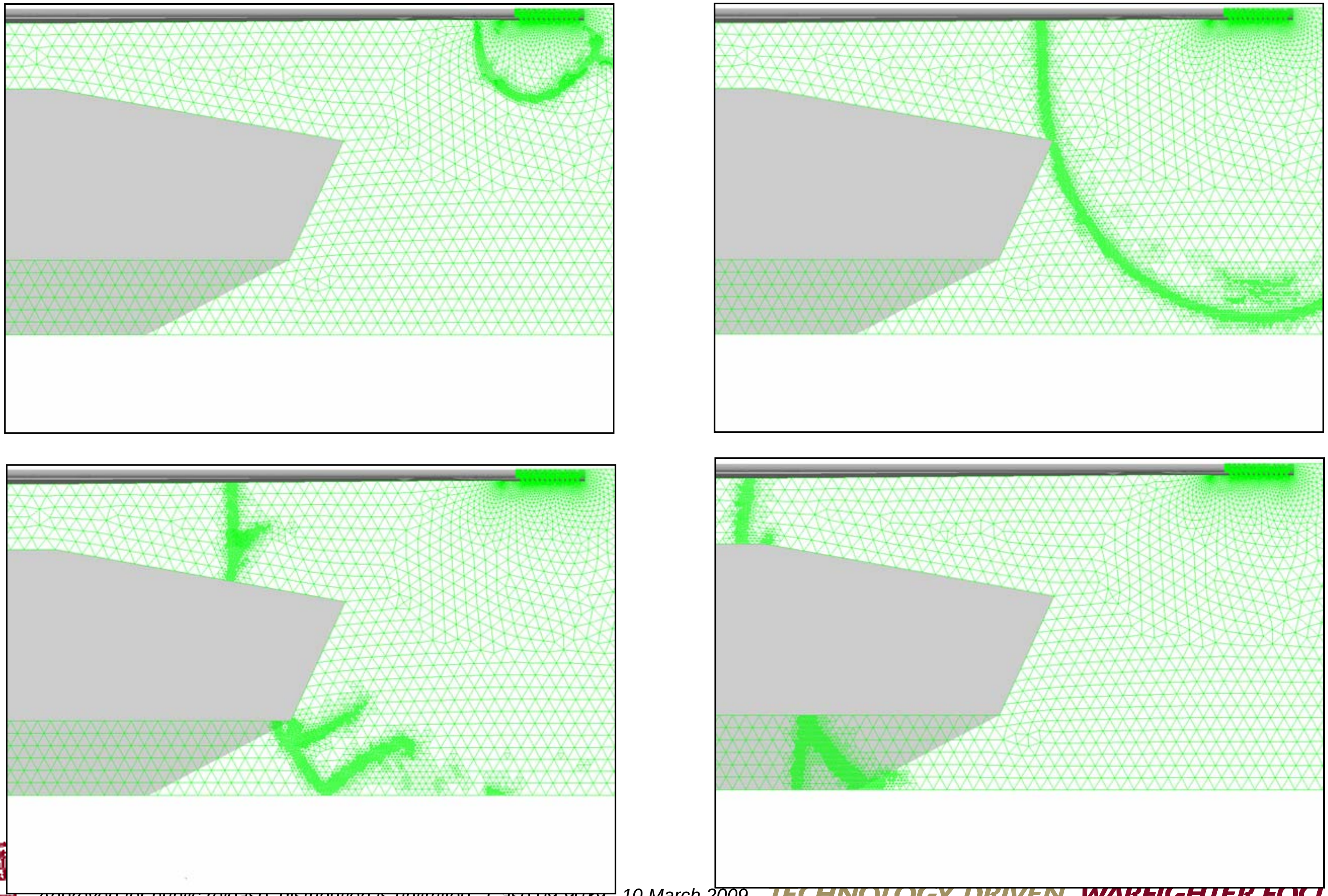




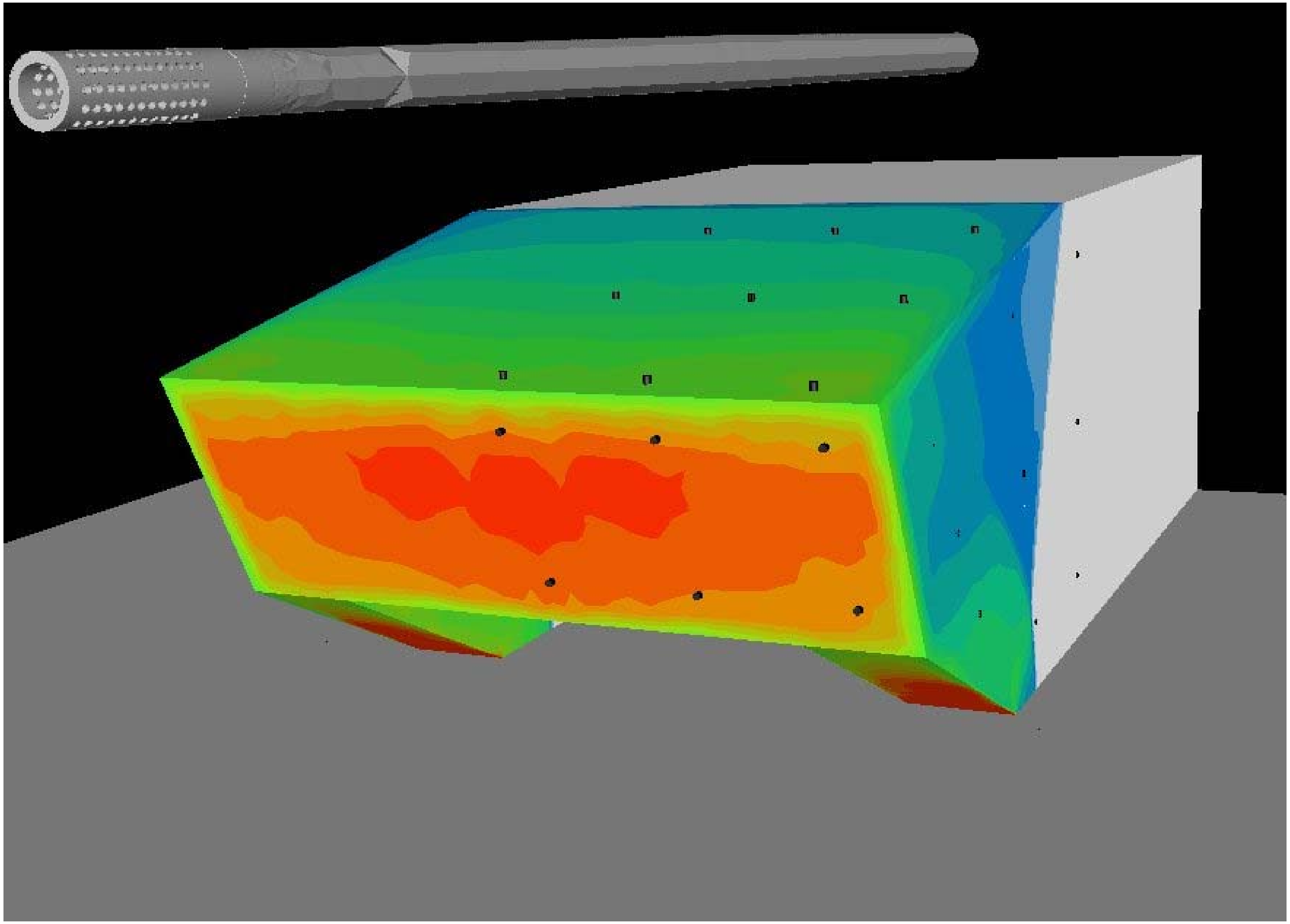




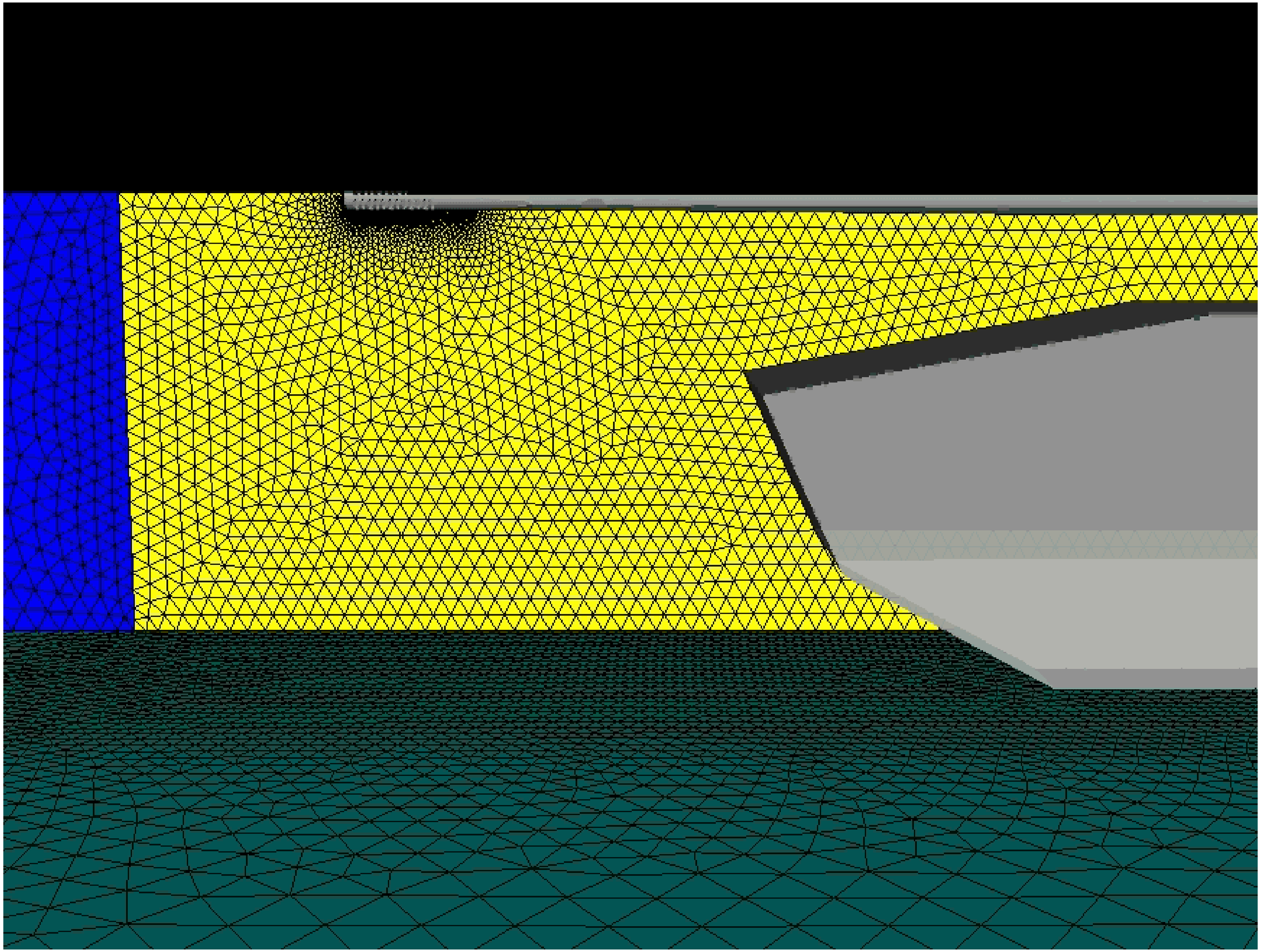
BWIP Validation
Dynamic Grid Adaption – XM360



BWIP Validation
Peak Overpressure Contour Plot – XM360

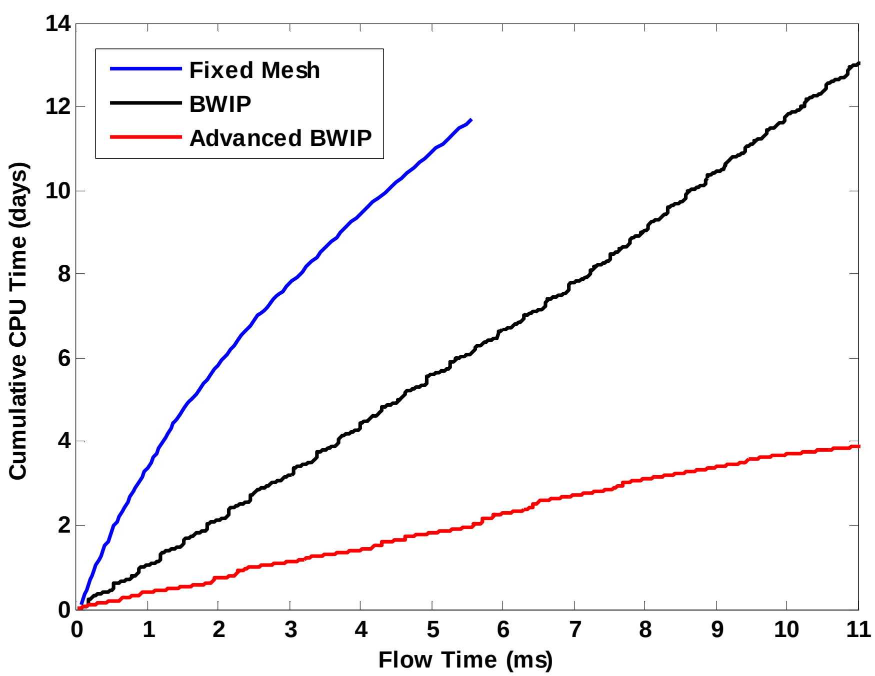


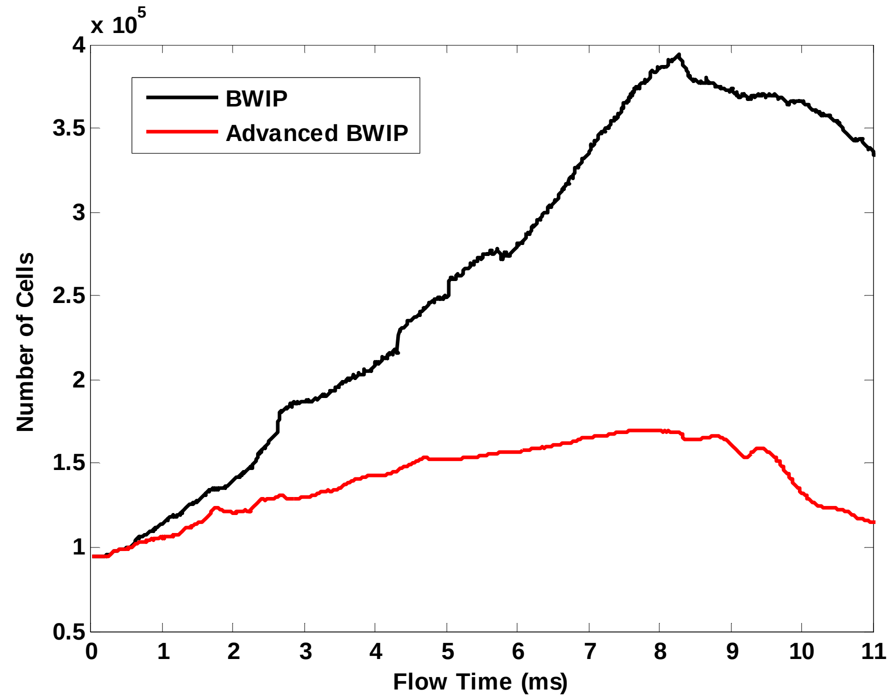
BWIP Validation
Dynamic Grid Adaption – XM360



BWIP 2-D Simulation Computational Performance Comparison

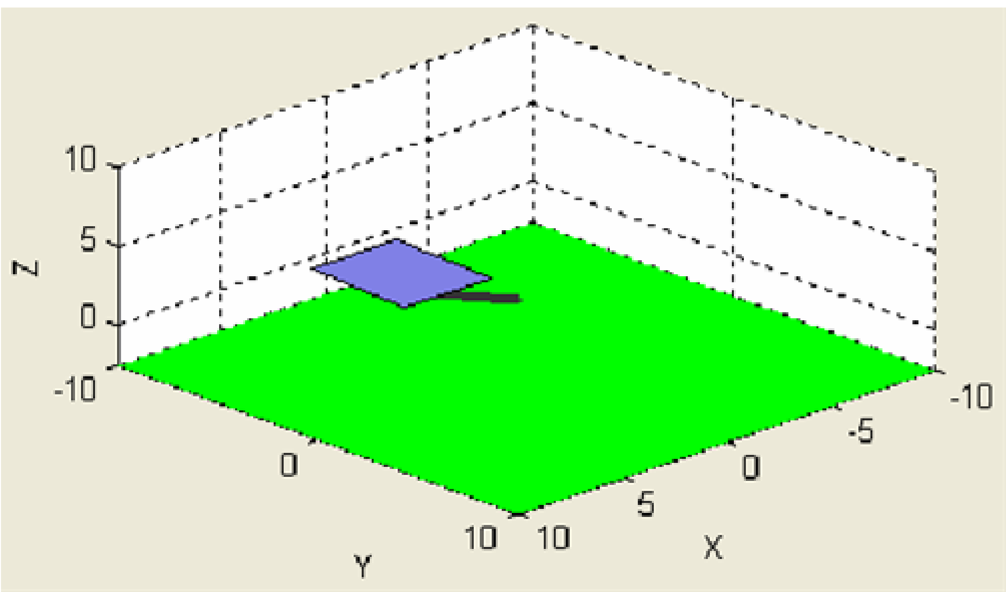
- 2-D simulation of Fixed Mesh, BWIP and Advanced BWIP.
- Advanced BWIP is one order of magnitude faster than a fixed mesh.
- Extrapolating to 3-D, we can see BWIP would be two or more orders of magnitude computationally faster than fixed mesh



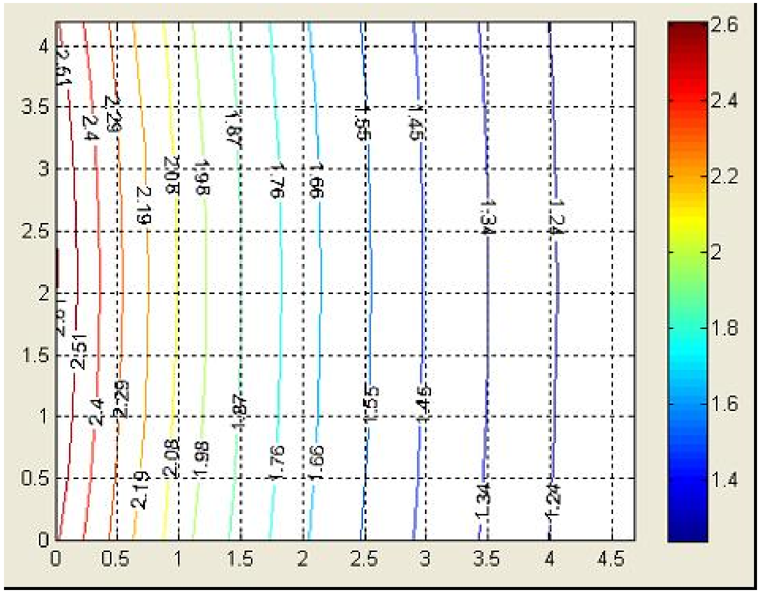


Empirical Blast Wave Modeling
3-D Fansler Blast Code

- Simplified Empirically Based Scaling Based On Fansler Blast Code
- Mat-Lab Based GUI Front End
- Input Parameters
  - Gun Geometry, Elevation and Azimuth
  - Vehicle and Ground Reflection Planes
  - Interior Ballistics
  - Muzzle Brake Efficiency



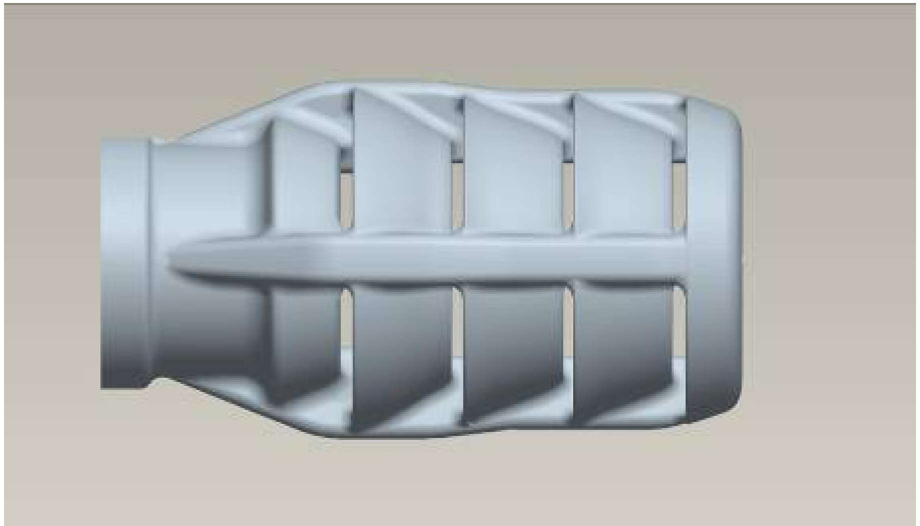
M256 Gun With M1 Abrams Turret Plane
Gun at 20 Degrees Elevation



Turret Peak Incident Pressure (psi)

XM-324 NLOS-C Muzzle Brake Thermal-Structural Analysis

- 3.5 Caliber Optimized Muzzle Brake
  - Maximum Efficiency
  - Short Length
  - Minimum Weight

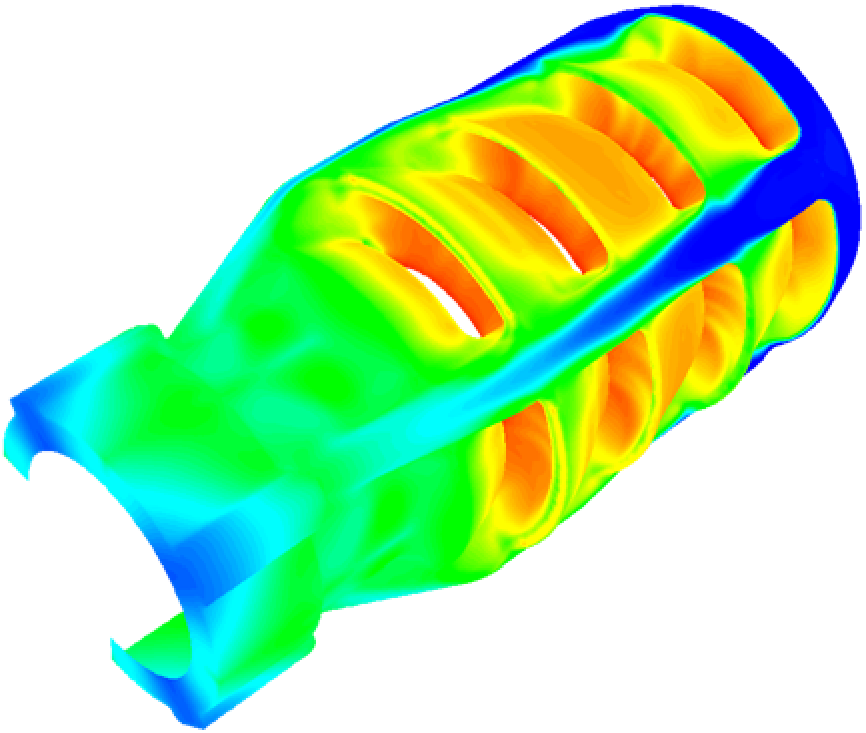


XM-324 NLOS-C Muzzle Brake Thermal-Structural Analysis

- High rate of fire cannon
  - 6 rounds/minute
  - Standard magazine
  - Standard reload
- Determine Temperature Field Prior to Last Shot
- Reduced Structural Properties
- Unsteady Structural Model For Last Shot
- Determine Peak Stresses and Structural Integrity
- Reduce Muzzle Brake Material In Low Stress Regions

Step 1: Fluent CFD Steady-State Convective Heat Transfer Analysis

- Steady-State Fluent Analysis
  - Vary Muzzle Pressure
  - Vary Wall Temperature
- Output
  - Surface Average Heat Transfer
  - 33 Separate Model Surfaces
- Utilizes Designed Experiments to Make Polynomial Models

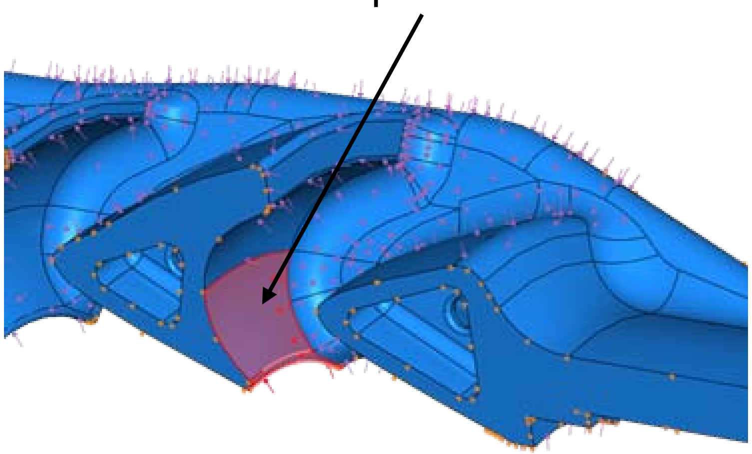


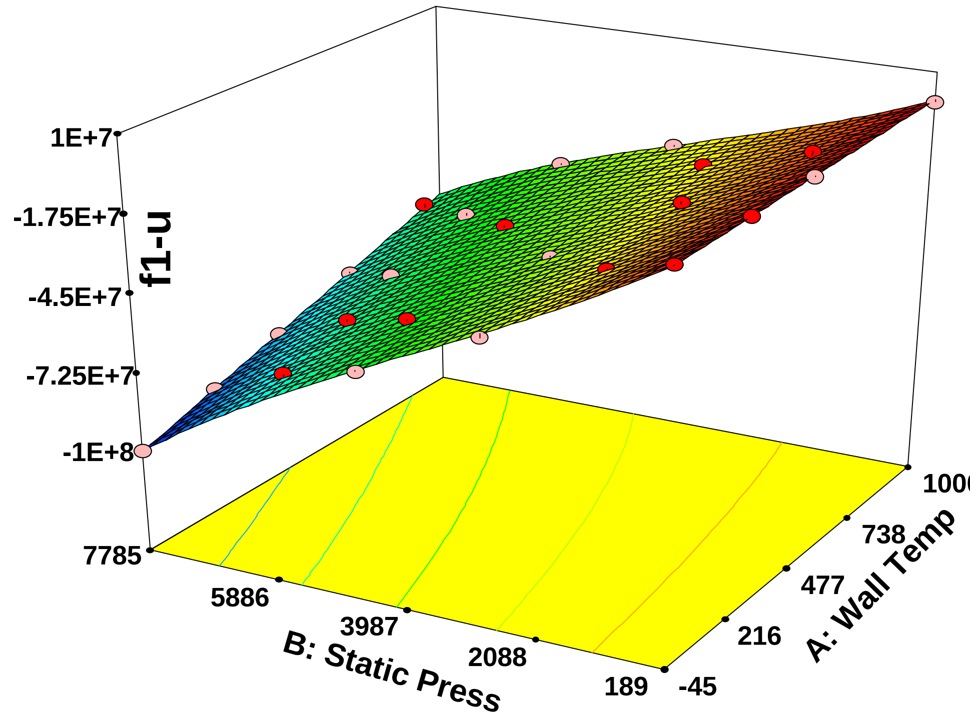
Contour Plot of Surface Total Temperature

Step 2: Develop Polynomial Models from Fluent Heat Transfer Data

- Develop a single cubic polynomial model of surface heat transfer for each of the 33 sub-surfaces.
  - Based on Muzzle Static Pressure
  - Based on Surface Wall Temperature
- Example polynomial model shown below for one surface.

Example sub-surface

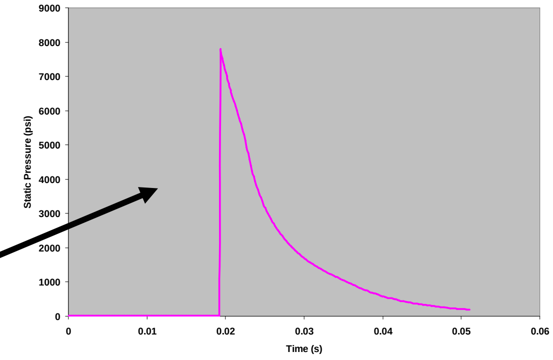


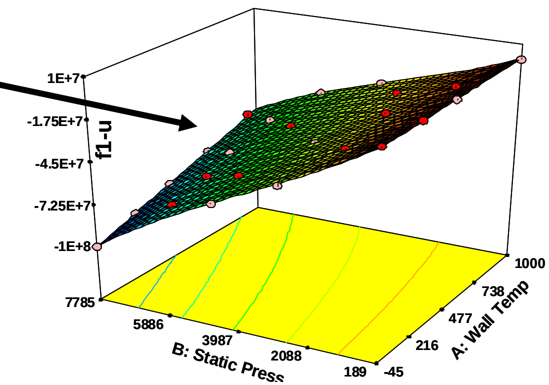


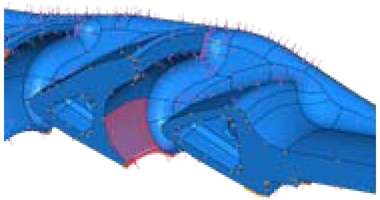
Step 3: ABAQUS Unsteady Thermal

<u>Goal – Determine Peak Temperature after Round 95</u>

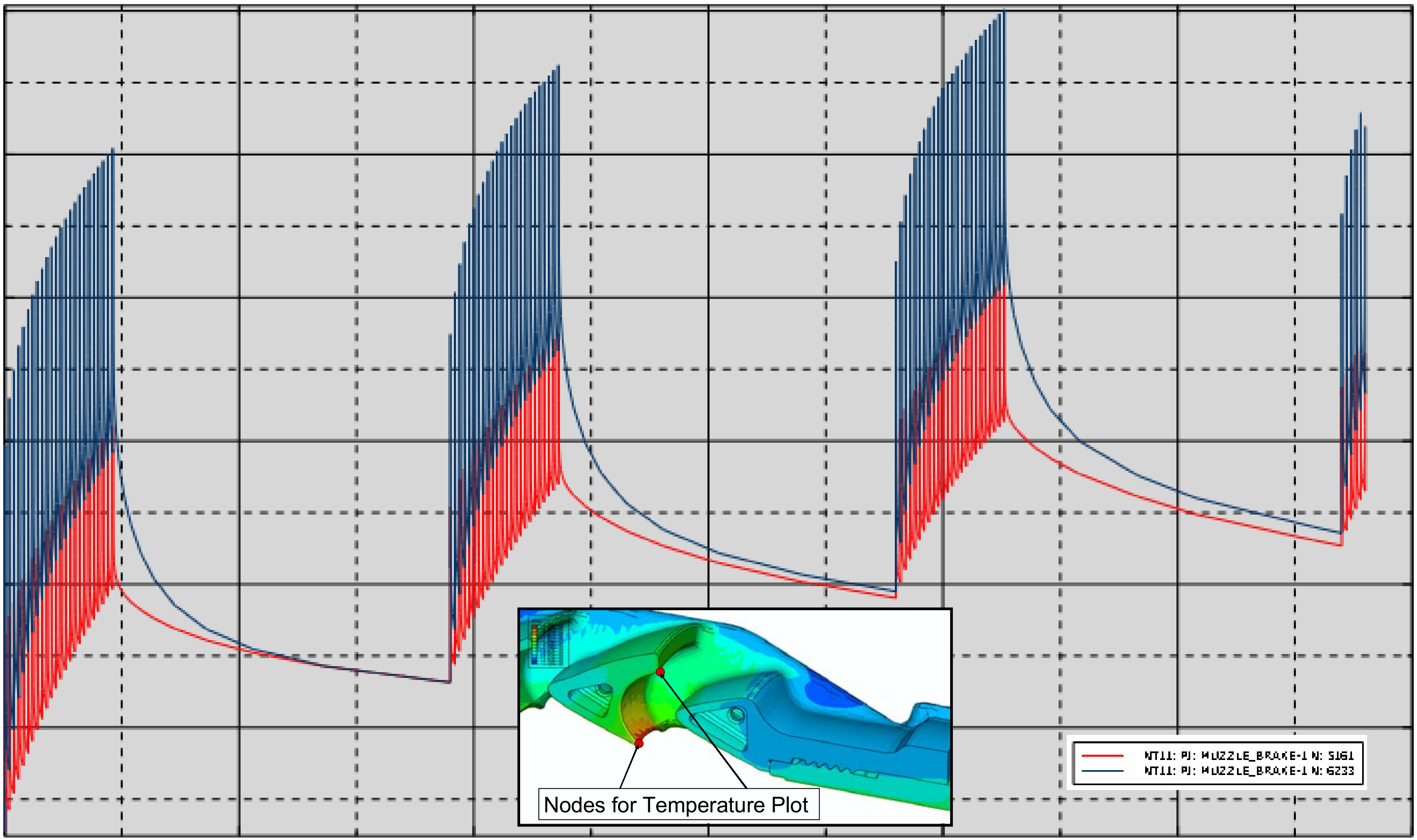
- Boundary Conditions
  - Firing Conditions
    - Forced convection heat transfer
    - Driven by polynomial pressure curve
    - Heat transfer boundary condition from Fluent polynomial model
  - Between Shot Conditions
    - Natural Convection Heat Transfer
    - Temperature dependent natural convection (no wind)
    - Solar radiation heat flux
    - Radiation to ambient
    - Ambient air temperature ≈ 54ºC







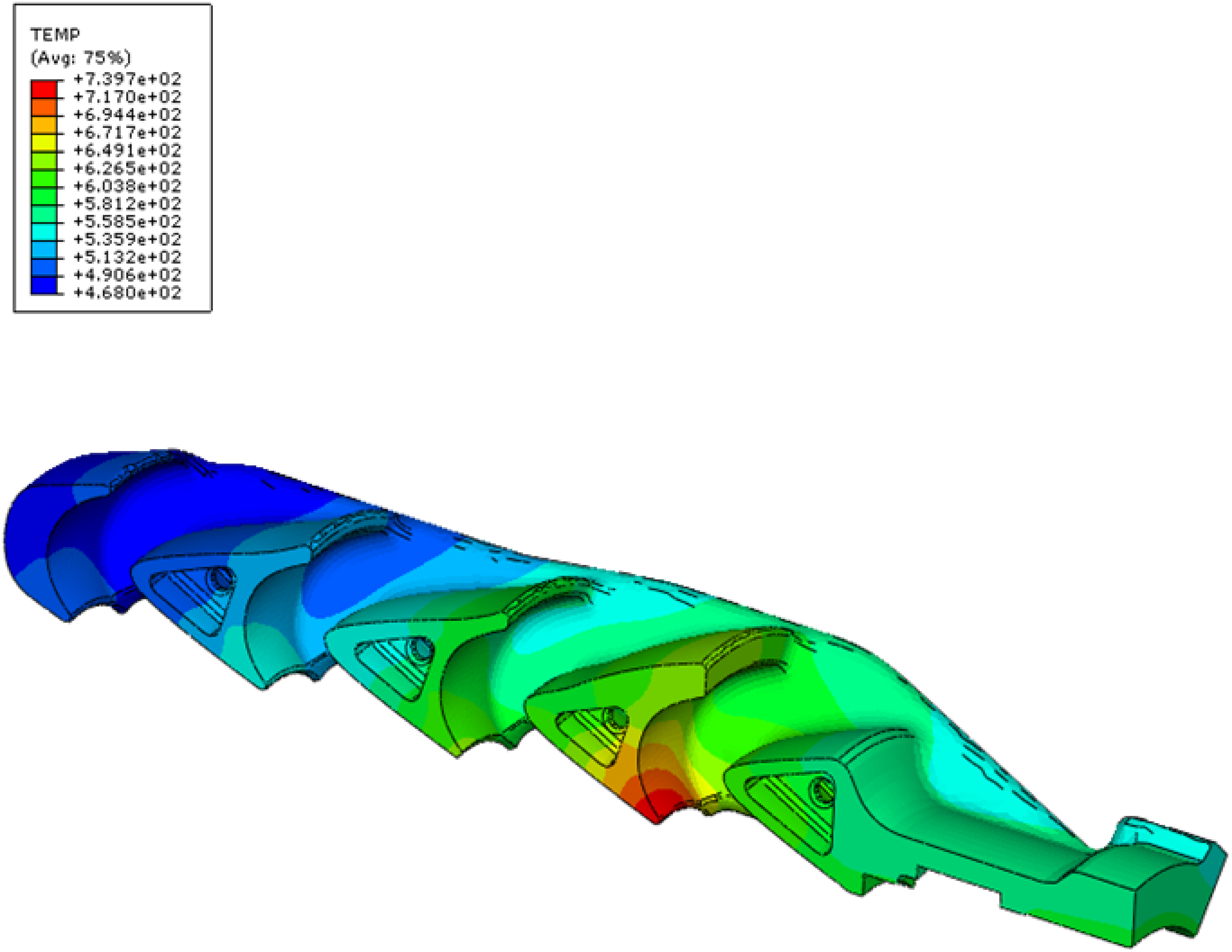
Step 3: ABAQUS Unsteady Thermal Surface Temperature vs Time



Step 4: Fluent Unsteady Loading Model

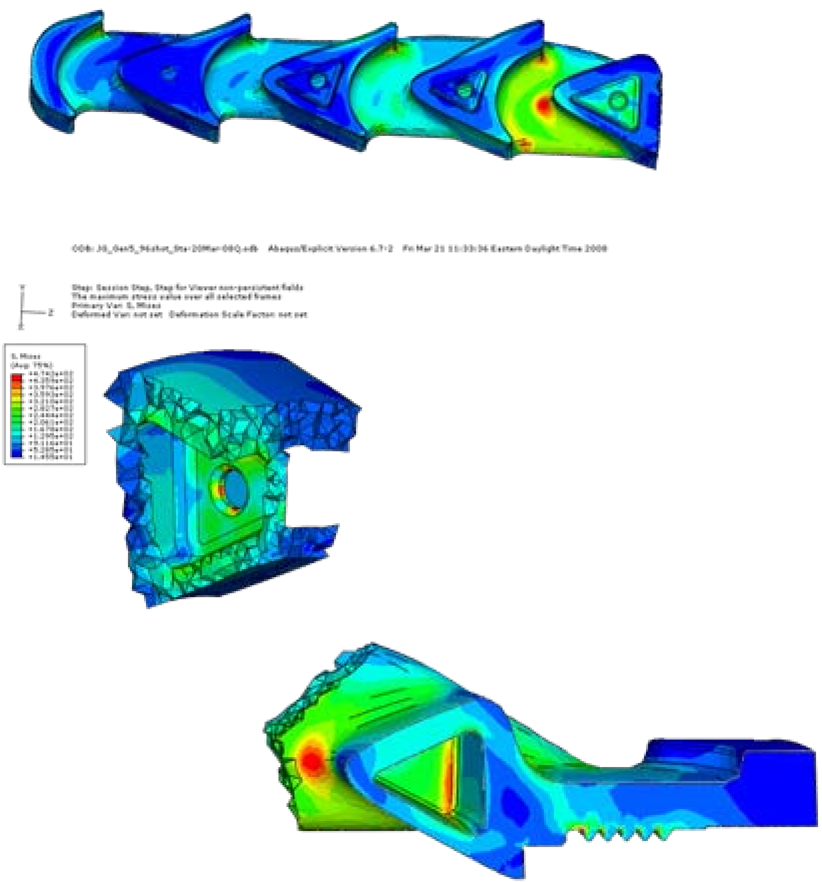
- Temperature and pressure patched into gun barrel based on projectile ready to enter muzzle brake.
- Flow allowed to expand using unsteady, coupled-explicit inviscid solver.
- Surface average pressure vs. time recorded during run for multiple surfaces.
- Used as input for unsteady ABAQUS structural model.

Step 5: ABAQUS Unsteady Structural Input Temperature Conditions

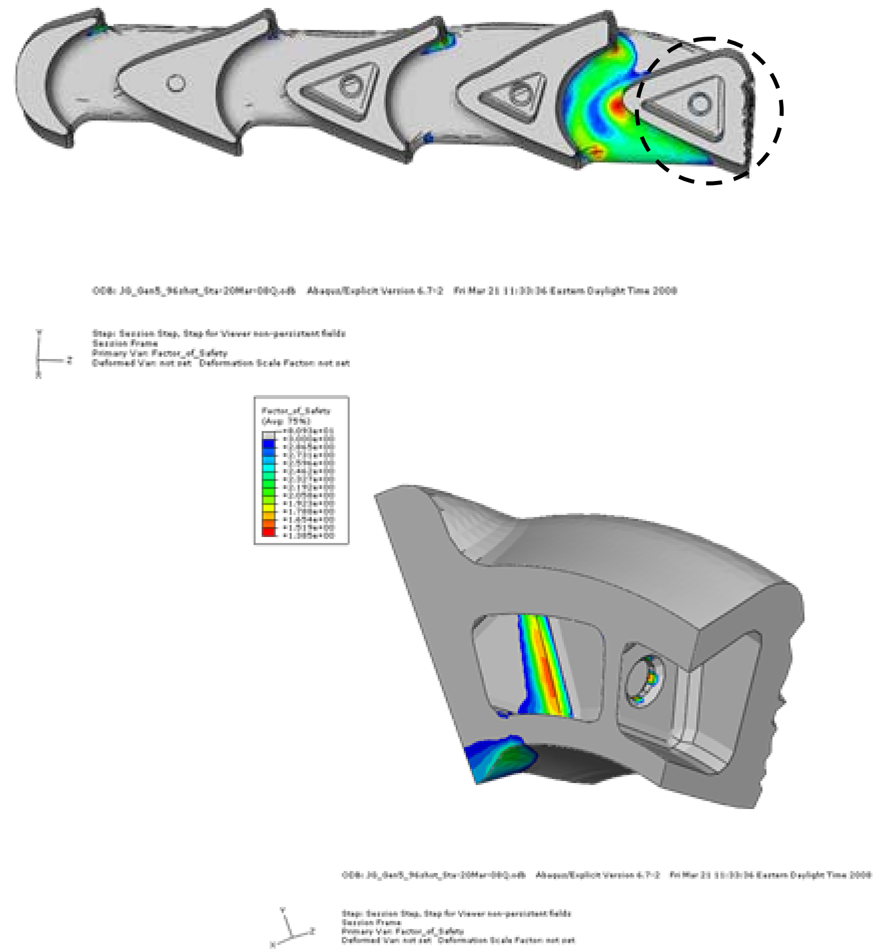


Step 5: ABAQUS Structural FEA Peak Stress Results

Results: Von Mises Stress

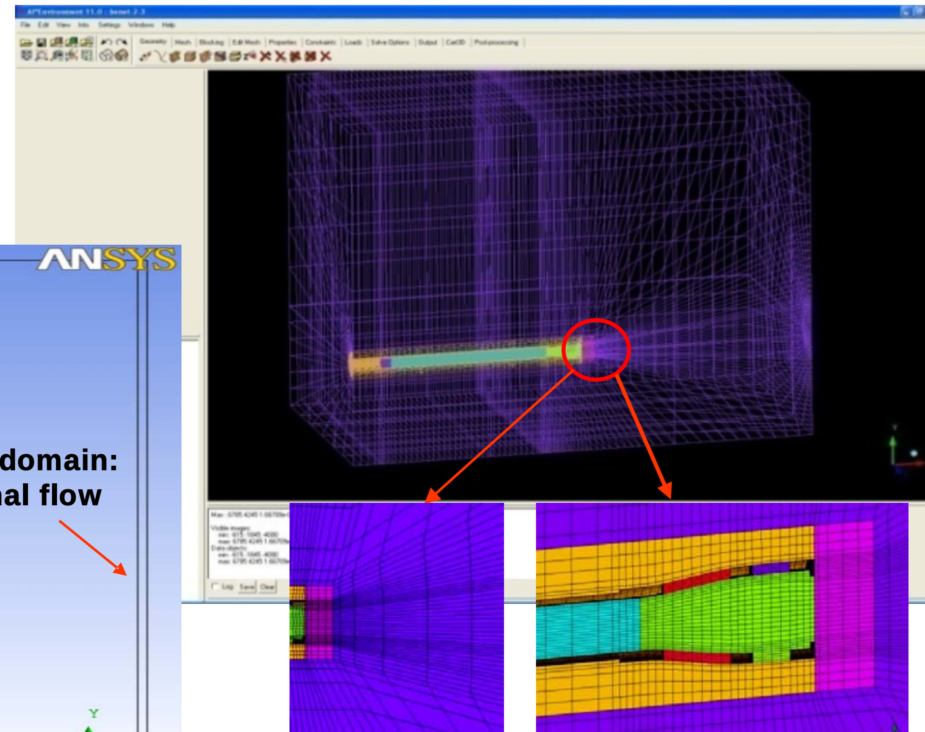


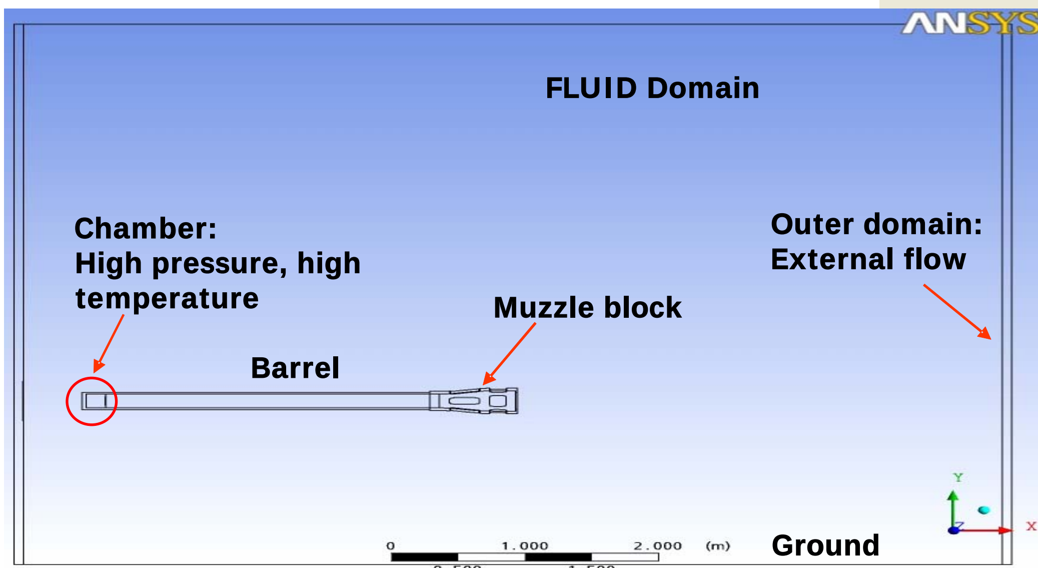
Results: Factor of Safety



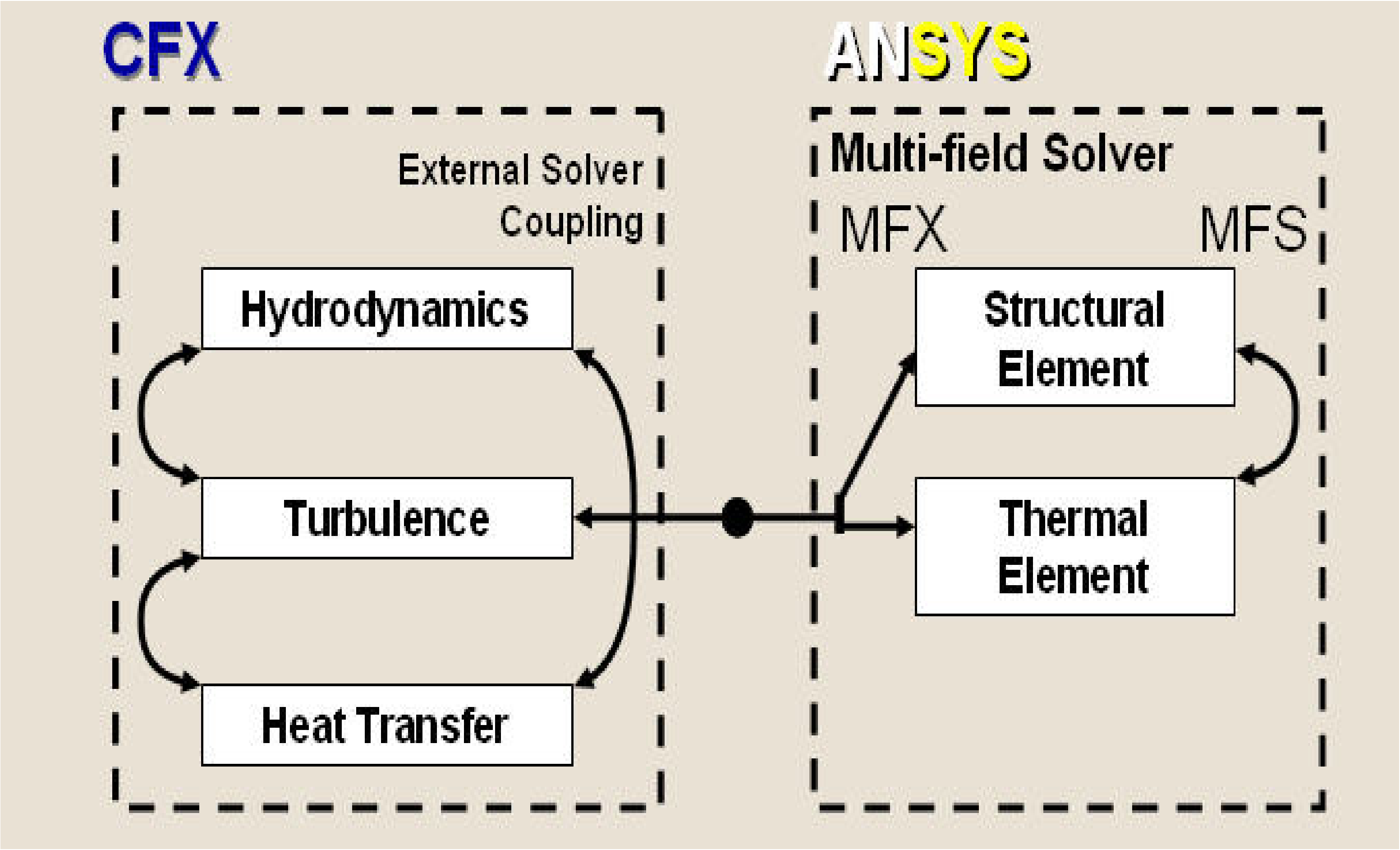
Fully Coupled Fluid-Structural Analysis Generic Barrel and Muzzle Brake

- Fluid Domain Simulated with ANSYS CFX
- Solid Domain Simulated with ANSYS Mechanical
- Full Two-way Coupling with ANSYS Multi-Physics



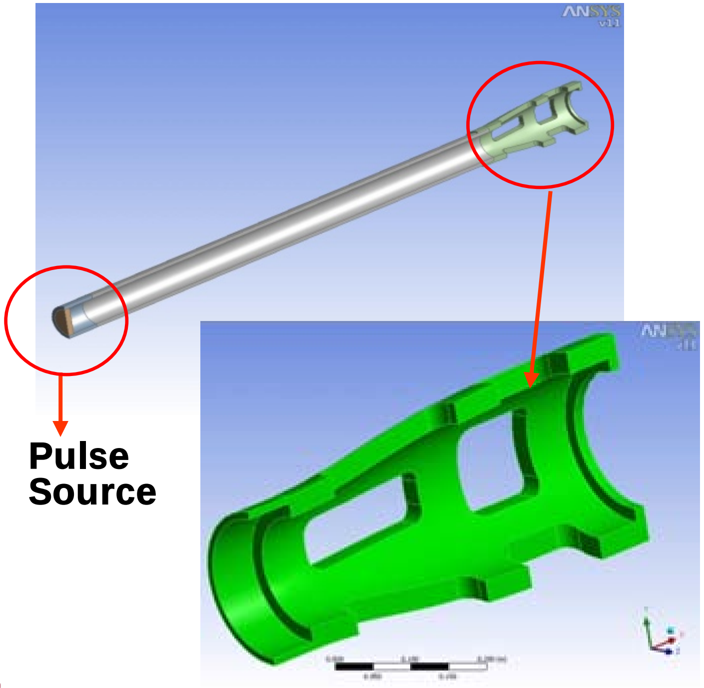


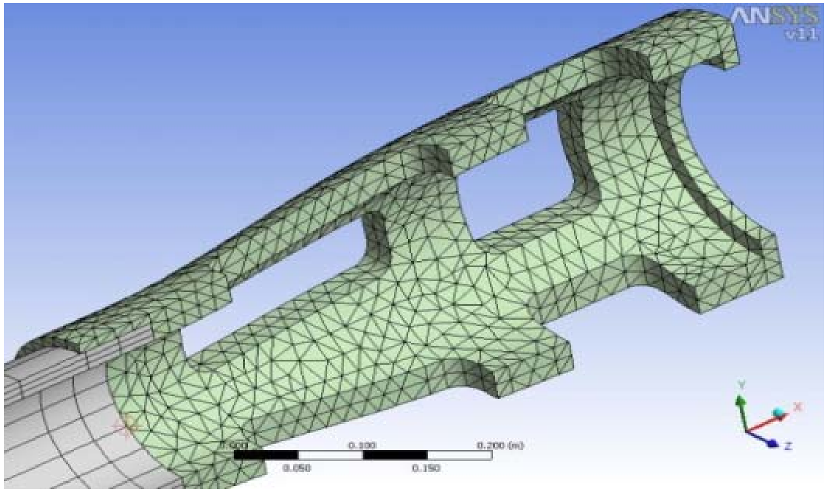
ANSYS Mechanical Multi-field Solver to CFX Coupling



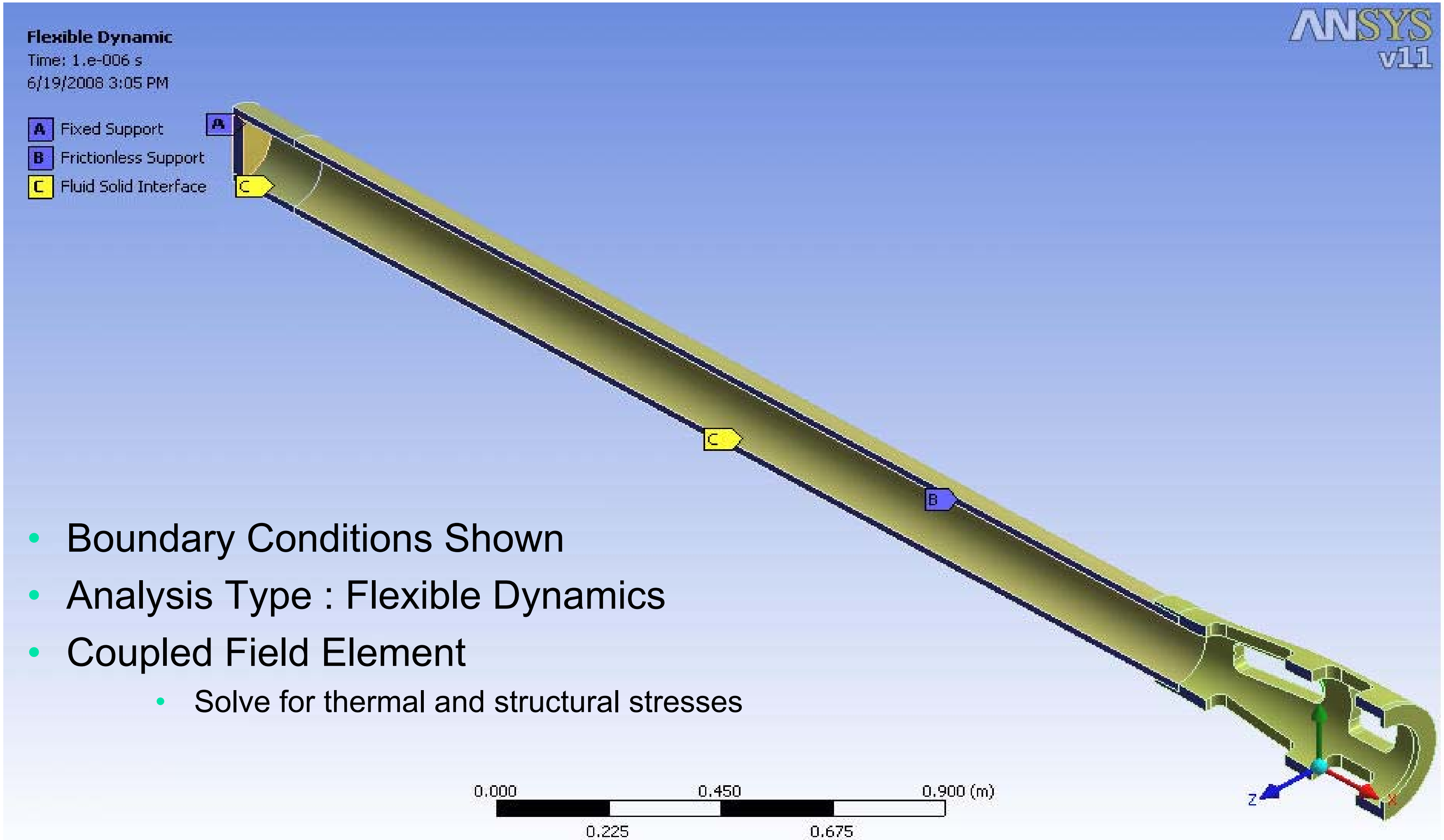
Mesh and Setup

- Solid mesh developed in ANSYS Workbench.
- Fluid mesh developed in ICEM CFD.
- Coupling and interfaces of two meshes done in ANSYS Workbench
- Pulse source term used in CFX to simulate gun firing.
- Structural deformation passed between to solvers.
- Multi-round mission simulated



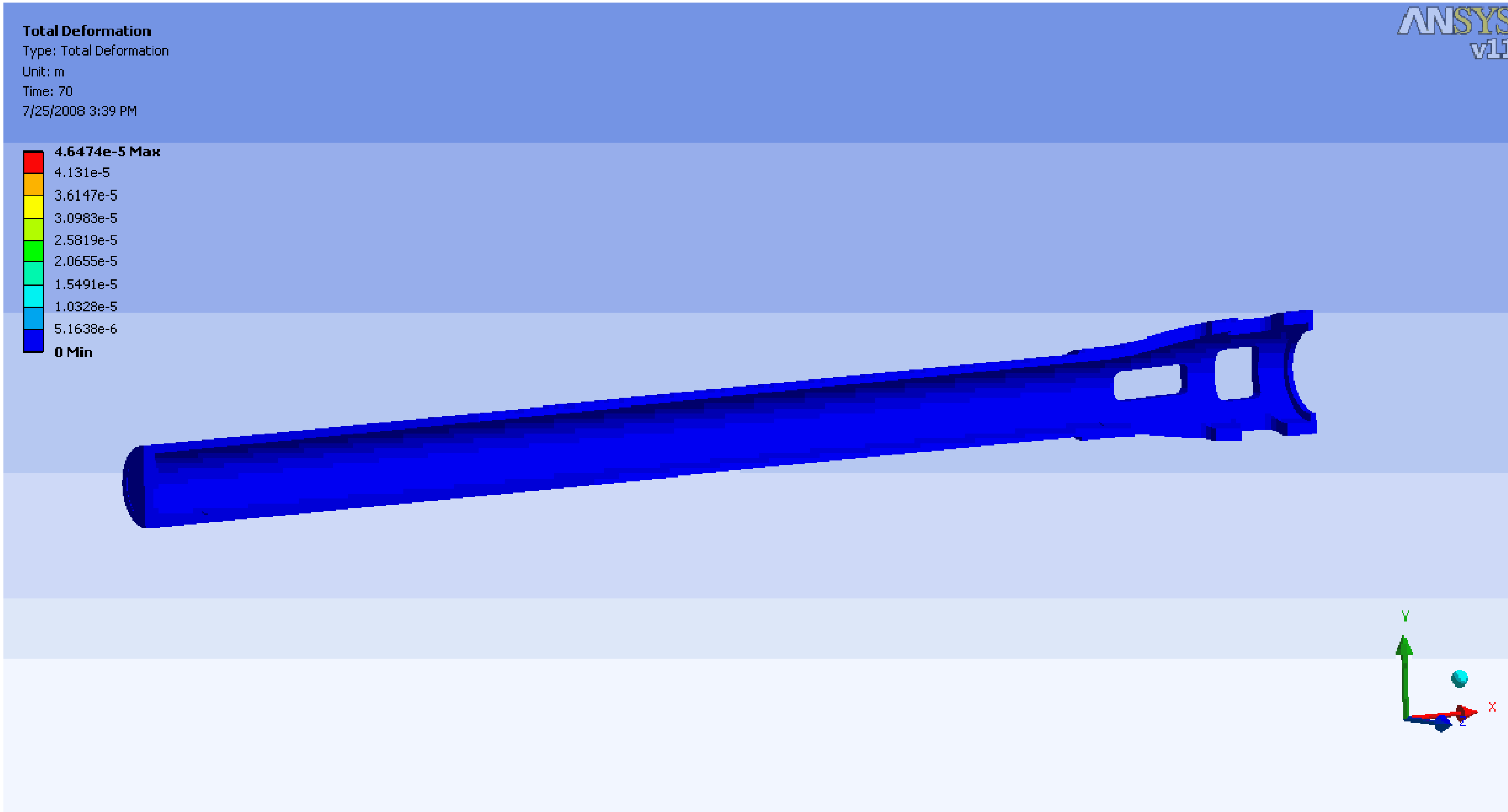


Workflow Snapshots
Mechanical Simulation Setup



- Boundary Conditions Shown
- Analysis Type : Flexible Dynamics
- Coupled Field Element
  - Solve for thermal and structural stresses

Workflow Snapshots
Mechanical Simulation Setup



Conclusions

- Advanced Design Tools:
  - Impulse modeling:
    - Full 3-D CFD analysis capable of predicting impulse with high degree of accuracy.
  - Blast modeling:
    - Low fidelity, quick estimates of 3-D blast fields with empirical models.
    - High fidelity models of complex 3-D blast fields with BWIP Based CFD models.
  - FSI:
    - Complex thermal-structure forced and natural convection modeling.
    - Full two-coupled structural response modeling of gun and muzzle brake structures.
- Results:
  - Higher efficiency, lower blast, lighter weight muzzle brakes.

GENERAL DYNAMICS
Armament and Technical Products

Qualification Testing of High Rate of Fire Gun Systems

Presented by:

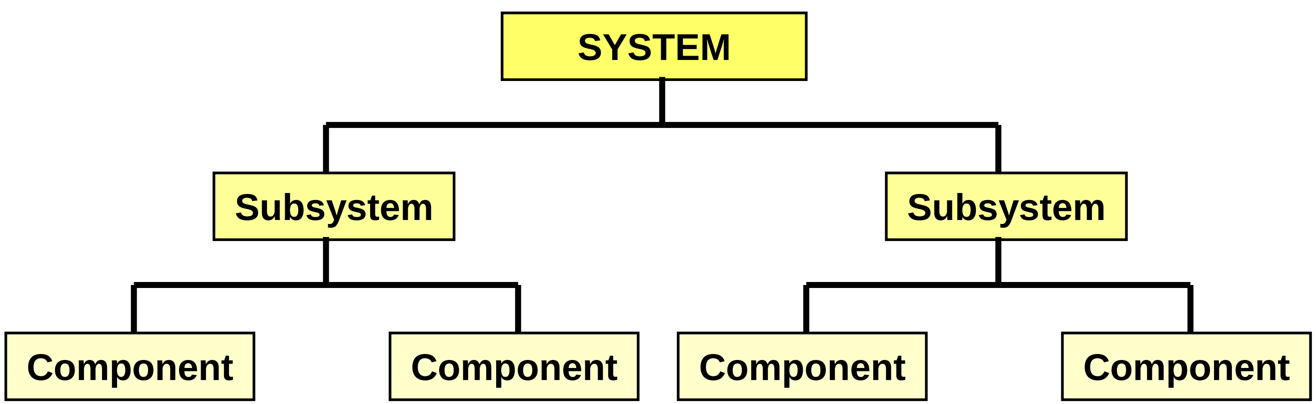
Dave Maher/Jim Talley
Project Engineer – Joint Strike Fighter Gun Systems
General Dynamics Armament & Technical Products
Burlington, Vermont USA
802-657-7113 dmaher@gdatp.com

Presentation Outline

- Qualification Methodology
- Gun System Qualification Test Approach
- JSF CTOL Qualification Results
- Conclusions

What is Qualification?

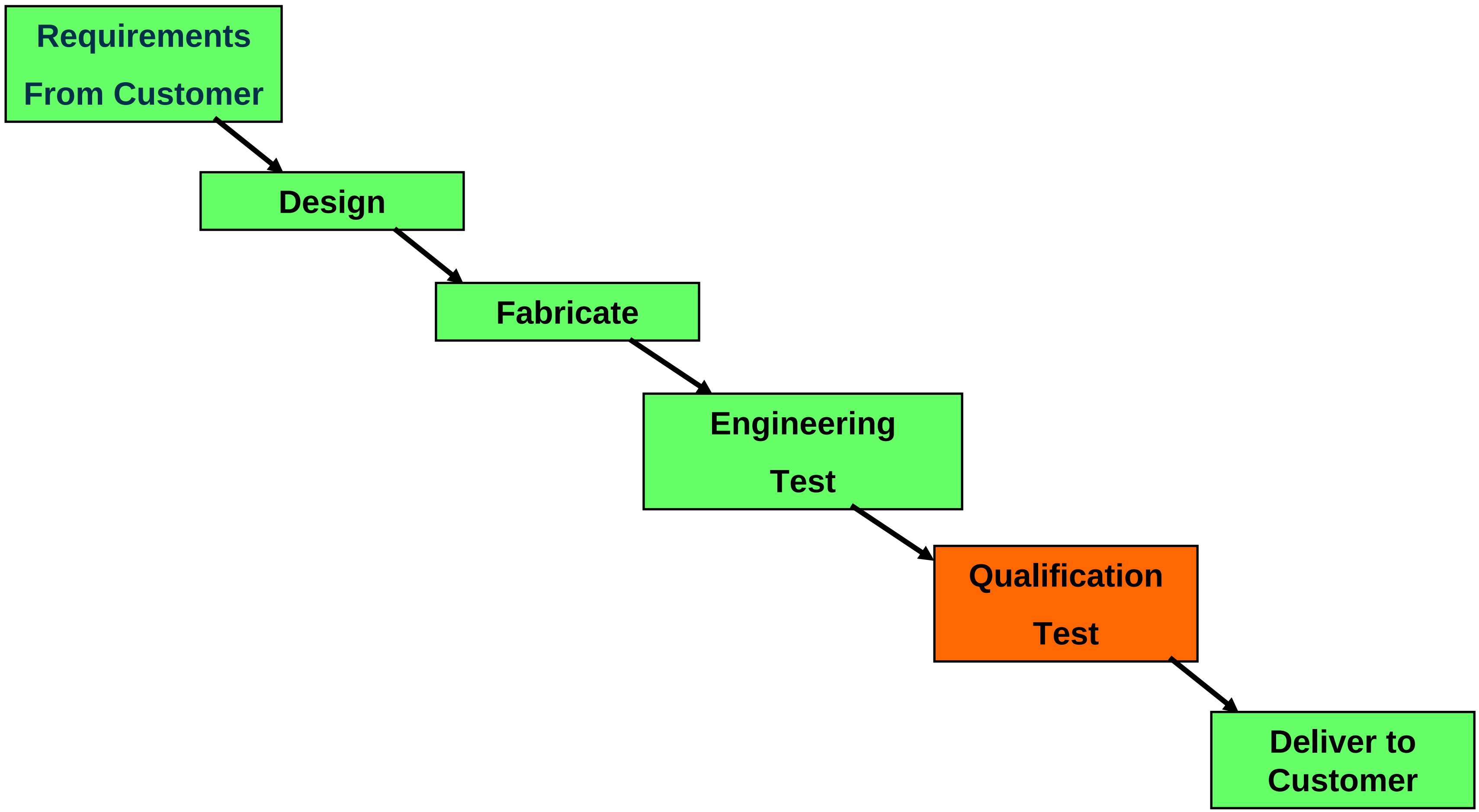
- Qualification is a process of verifying that a design meets its allocated requirements.
- Qualification is usually done in a systematic manner, starting with lower level components and subsystems, and working up to the system level.



System Perspective

The distinction between a system and a subsystem is a matter of perspective

Where does Qualification fit?



Qualification Methods

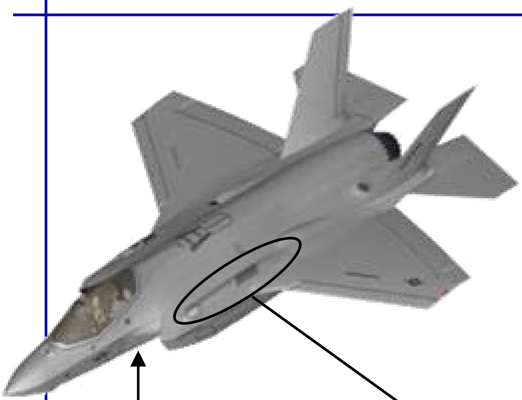
- Analysis – Technical assessment using detailed calculations, including computer modeling.
- Demonstration – Simple, uninstrumented go-no go result
- Examination – Visual inspection
- Similarity – Based on qualification results of a similar product in a similar environment .
- Test – Measurement of performance while operating the system

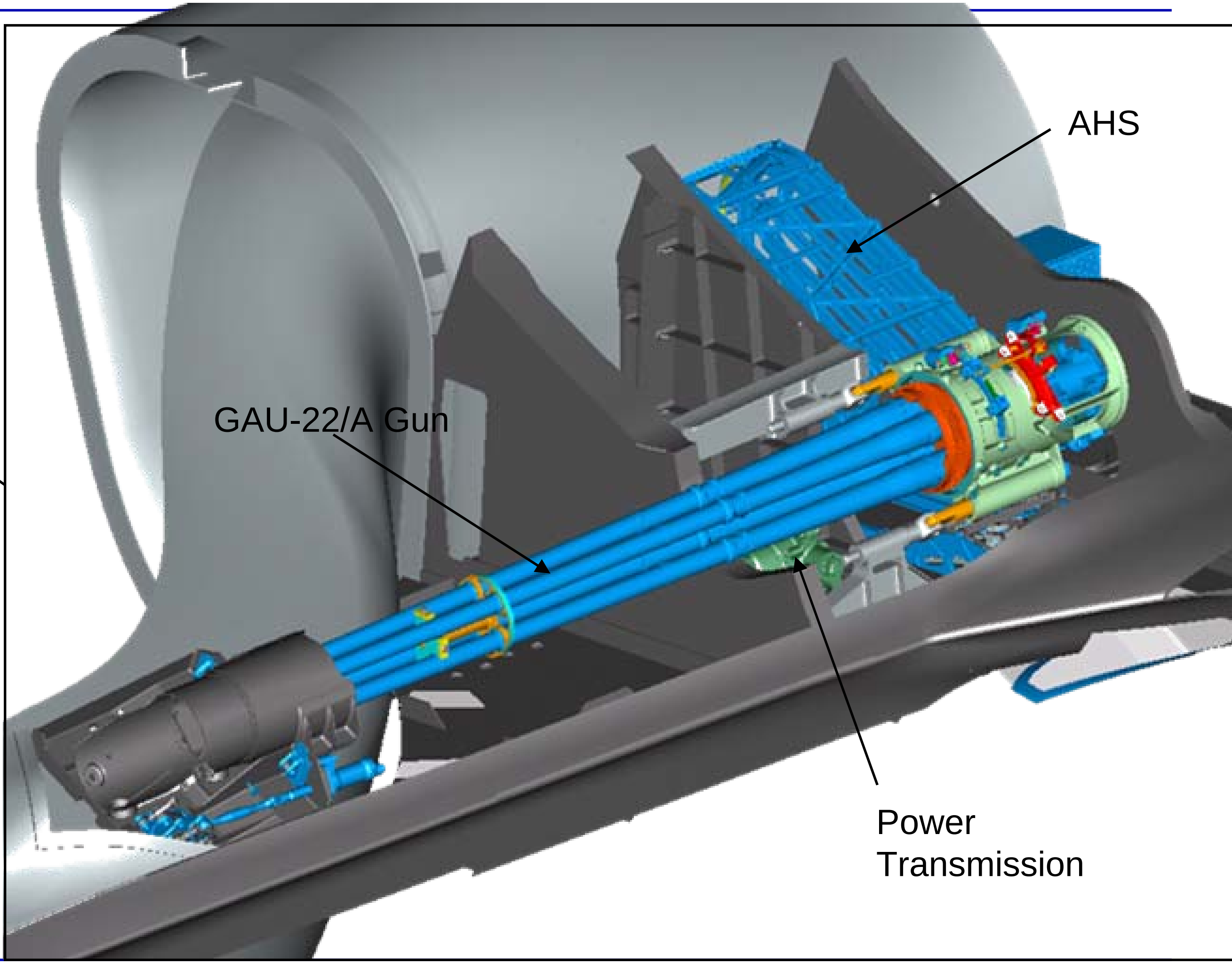
Typical Gun System Architecture

- Gun System
  - Gun Assembly
    - Gun
    - Transfer Unit
    - Solenoids
    - Prox Sensors
  - Ammunition Handling System
  - Power Transmission
    - HyDrive
    - Prox Sensors
    - Driveshafts
    - Gearbox
  - Gun System Control Unit
    - Hardware
    - Software

Lower Level Qualification

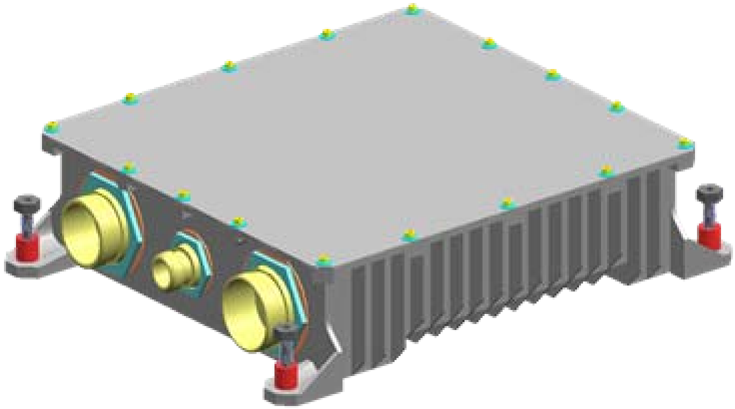
JSF CTOL Example





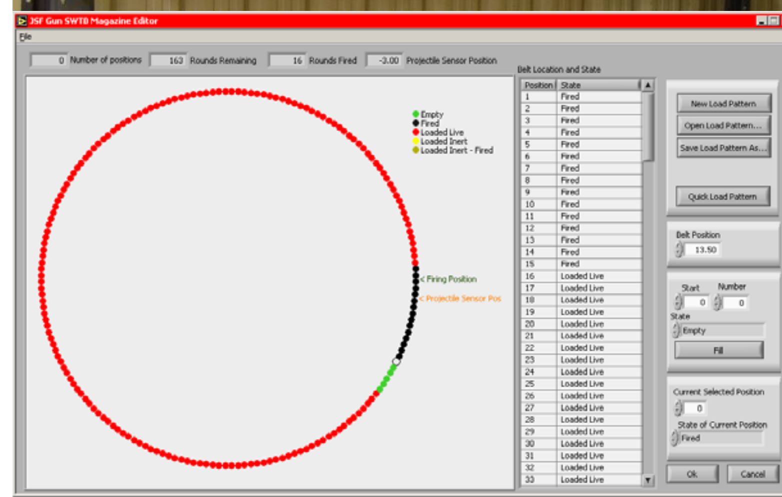
GSCU HW Qualification Tests

- Electrical Characteristics
- Electromagnetic Interference
  - Conducted Emissions and Susceptibility
  - Radiated Emissions and Susceptibility
  - Electrostatic Discharge
- Mechanical
  - Shock and Vibration
  - Humidity, Rain, Ice
  - Altitude and Air Pressure
  - Corrosion



GSCU Software Qualification

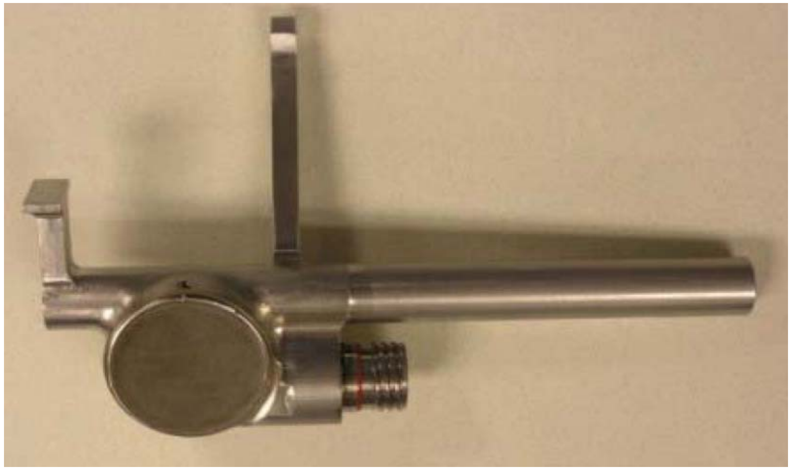
- All Software Requirements Verified
- Tests conducted with prototype GSCU and “Software Testbed” that emulates the Gun System.
- Testing conducted independently.



Proximity Sensors

- Electrical / Functional Characteristics
  - Sensing Range
  - Temperature
  - Voltage Levels
- EMI
  - Conducted Emissions and Susceptibility
  - Radiated Emissions and Susceptibility
  - Electrostatic Discharge

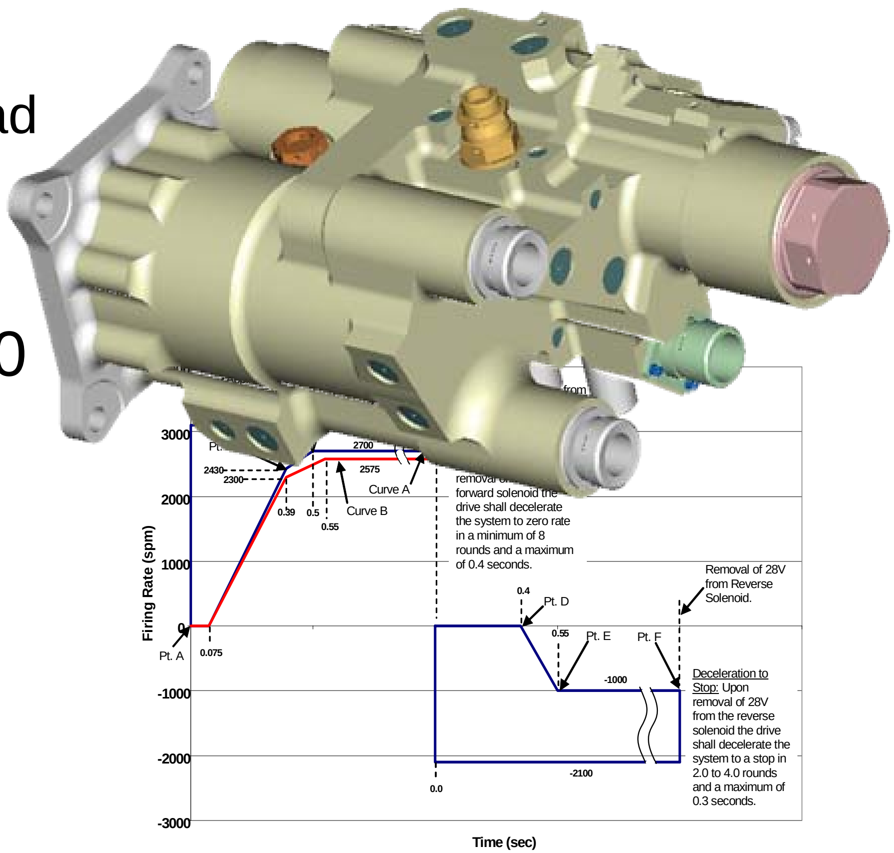
Gun Motion Sensor



Projectile Sensor

Hydraulic Drive Motor Qualification Tests

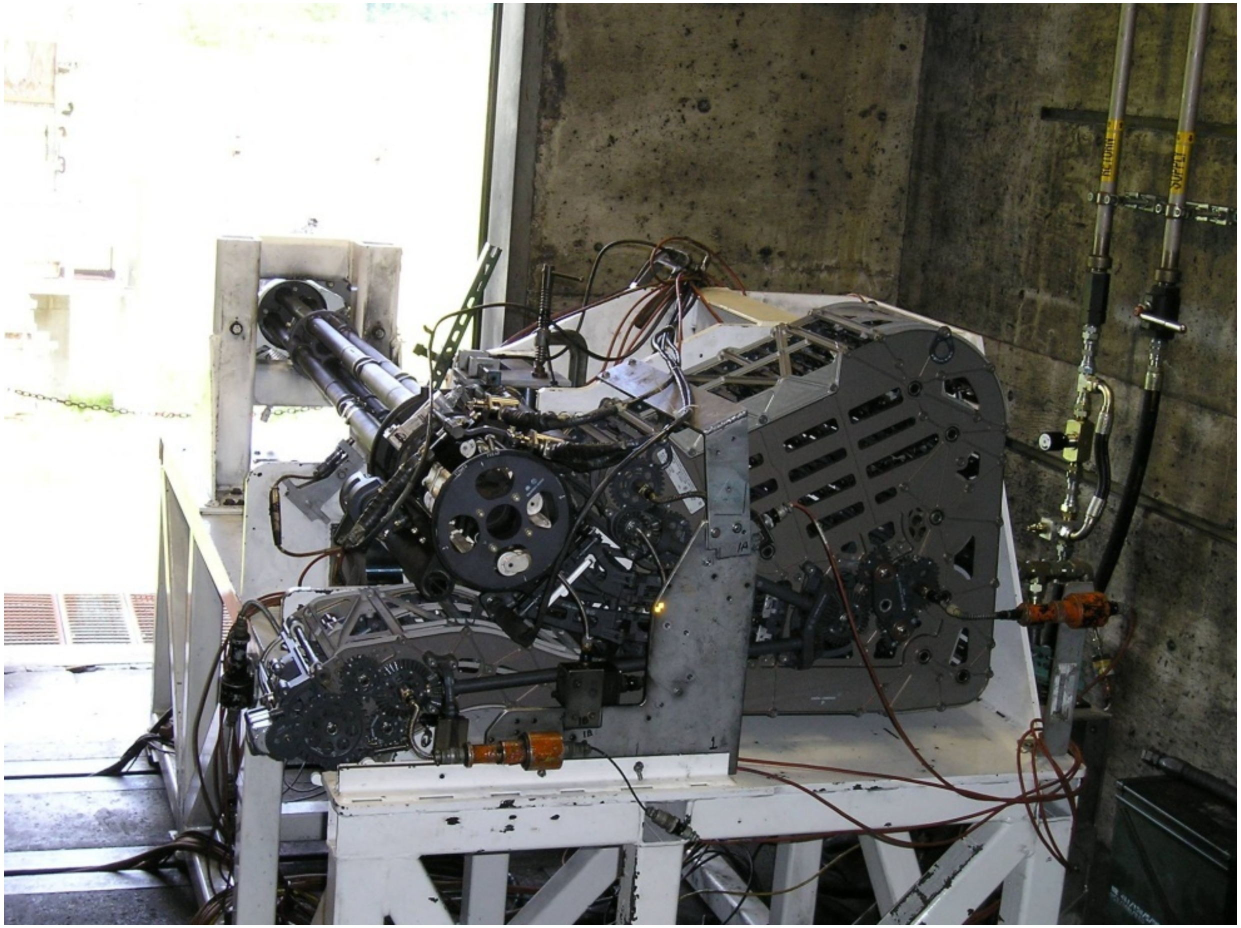
- Performance Mapping
  - Temperature, Pressure, Load
  - Speed and Power
  - Rounds to Stop
- Impulse Pressure (100,000 cycles)
- Burst Pressure
- Warming Flow
- Shock and Vibration



JSF System Level Qualification Tests

- 36,000 Round Durability Test (2X Life)
  - Fatigue
  - Wear
  - Barrel Performance
  - Hot and Cold Temp
  - Clearing
  - Dispersion
- Environmental Test
  - Shock,
  - Vibration
  - Limit Load (centrifuge)

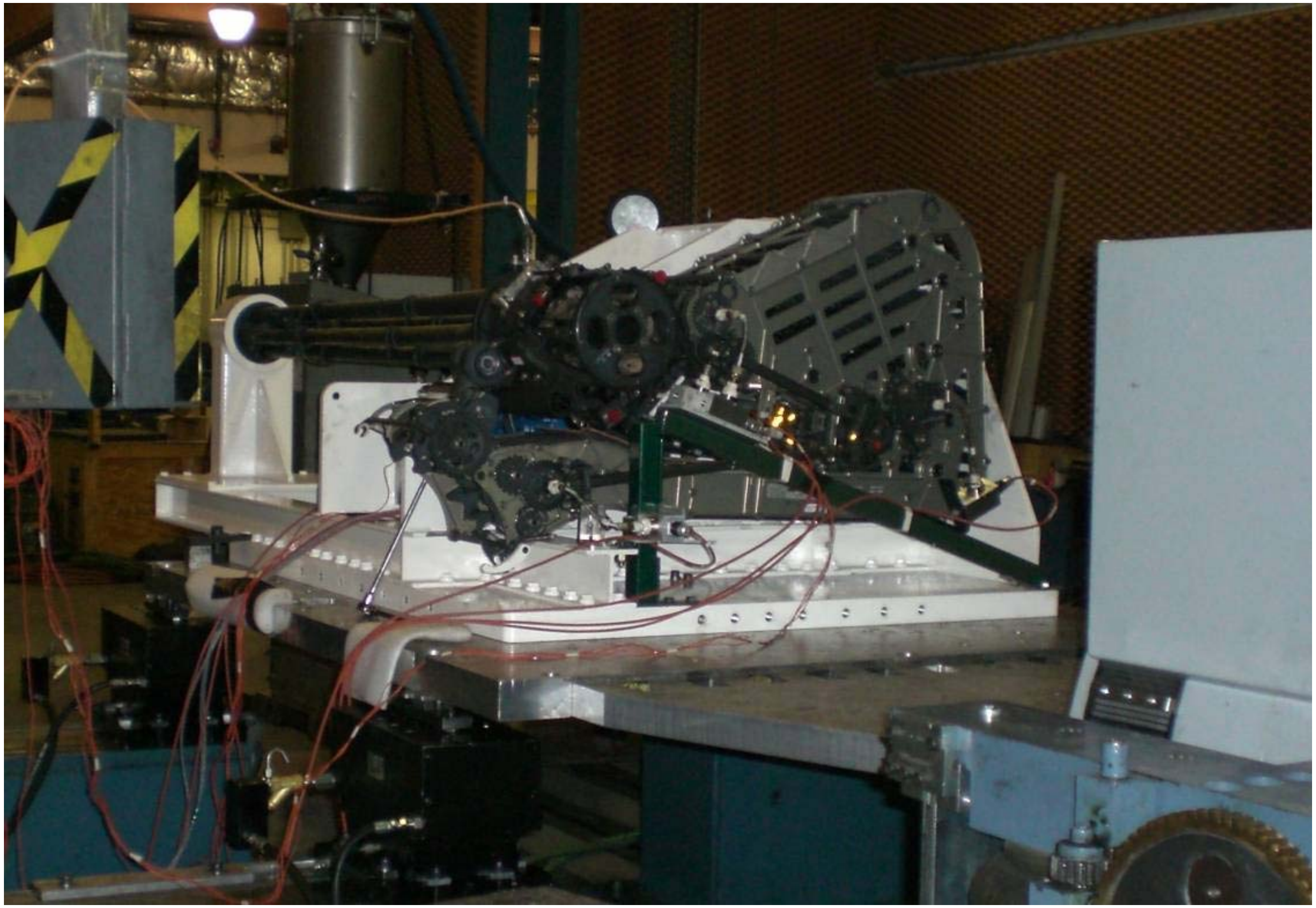
JSF CTOL Fire Test Set-Up



36,000 Round Endurance Test – Key Results

- Outstanding reliability demonstrated.
- No gun jams occurred in over two lifetimes of fire testing.
- No significant increase in dispersion after two lifetimes.
- No broken parts
  - Fatigue cracks were found on some parts, but none were beyond acceptable limits.
  - Where possible, design changes were implemented to eliminate cracking.

Environmental Test Set-Up



Environmental Test – Key Results

- JSF CTOL Gun System passed all environmental test requirements.
- Dummy ammunition failure (separated nose cone) damaged Ammunition Handling System.
- Stronger spring implemented in Load Access door latch.
- Pin in slot mounting interface strengthened to reduce fretting wear.
- Internal parts modified to eliminate minor cracking.

Conclusion

- A systematic approach resulted in a highly successful qualification test, as a prelude to flight test.
- Results of qualification testing frequently lead to design improvements.
- Overall, the JSF CTOL Gun System demonstrated exceptional reliability during qualification testing.
- Lessons learned are being applied to the Missionized Gun System, scheduled to begin qualification testing later this year.

A rigorous qualification program results in a better design and reduces risk at the next level of test.

GENERAL DYNAMICS

Different approach to establish an armament system baseline

Mohan Palathingal
Yu Lu
US Army, RDECOM-ARDEC
Picatinny Arsenal, NJ 07806-5000

Overview

- Conventional design of new armament systems is not fully integrated
- Proposing an *integrated approach* to provide *first order estimate* of projectile and gun using optimization methods
  - Individual models of the projectile and gun are not the primary focus
  - Emphasis is on the framework for arriving at the baseline system
- The hope is to use this approach to:
  - Help systems developer narrow down the design space
  - Provide subject matter experts (projectile and gun) with starting point for further exploration of projectile and gun designs

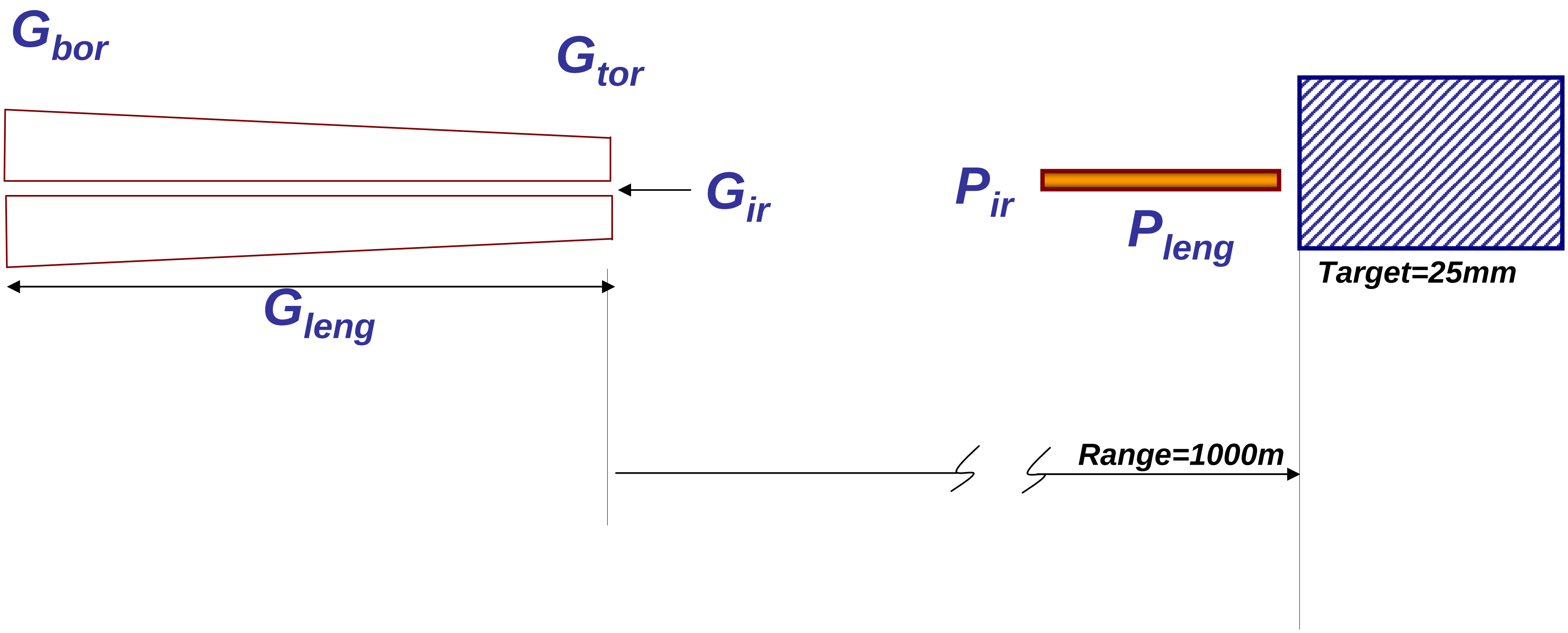
Approach

- Simple Quasi static model set up in ANSYS with constraints imposed due to practical consideration for the bullet and weapon
    - Full Bore penetrator (base pushed; no sabots)
    - Simple tapered pressure vessel to simulate Weapon

  – Loads on model:
    - Normalized pressure travel curves from actual Large caliber & Small caliber data (no IB code coupled with the model)

- Design Optimization module in ANSYS is used for iterative design

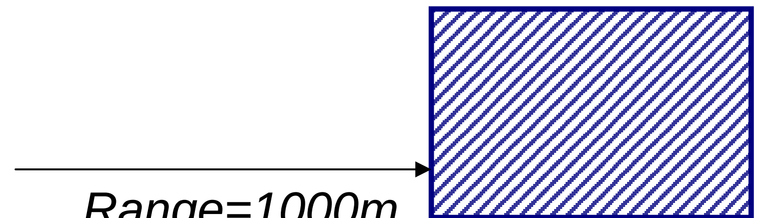
Projectile & Gun Parameters



Algorithm

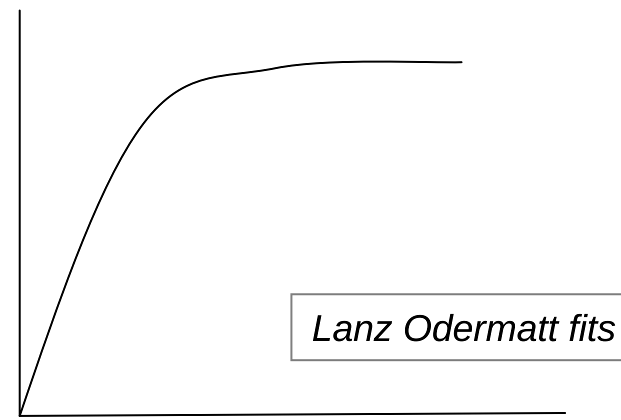
Working the problem backwards:

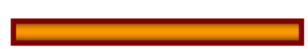
1. Begin with Target thickness and Range requirements (say 25mm at 1000m)



2. *Projectile design space*:

- Establish *range* of penetrator parameters
  - Establish length range such that penetration does not exceed 1.2 times the length (practical considerations):
    - example $0.85L<P_L<1.5L$
  - Establish diameter range such that:
    - Eg. L/D ratios in the range of 5<L/D<15





Algorithm

3. Calculate striking velocity for that penetrator configuration to defeat the target

4. Calculate velocity falloff, use point mass estimates (from diameter and mass).

5. Calculate muzzle velocity from velocity fall off and the defeat range.

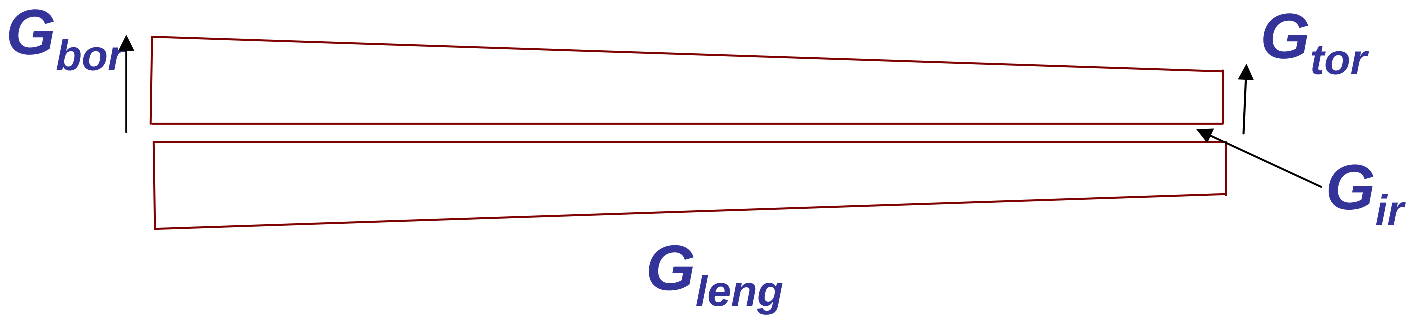
6. Calculate Muzzle energy (from projectile mass and muzzle velocity)

Algorithm

3. *Weapon Design Space*:

- Complex gun tube design considerations (auto frettage, critical velocity, thermal considerations etc) are not considered for this illustration.
- Chambrage and breech block features and recoil omitted for simplicity but could be added in other versions.

Since we have a full bore projectile, the gun bore is set as the projectile diameter + clearance



– Establish a range of acceptable gun tube lengths ***Gleng*** (in this model, its set equal to travel) that is acceptable to the customer (say from 0.5m to 2.0m)
– Optimization routine picks ***Gleng*** from the range

Algorithm

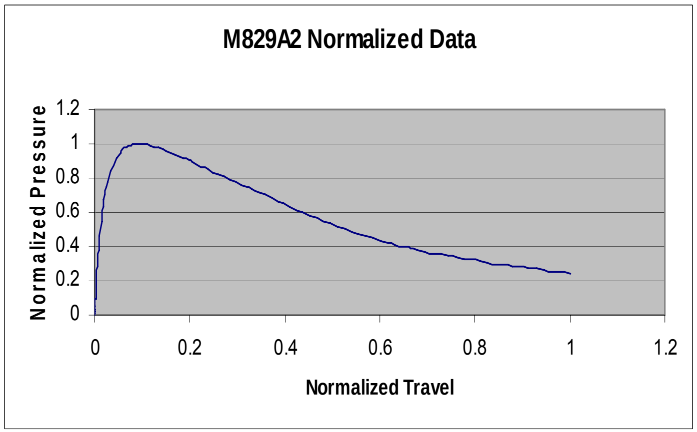
- Since required muzzle energy is now known, and Gleng is known, the mean base pressure can be calculated

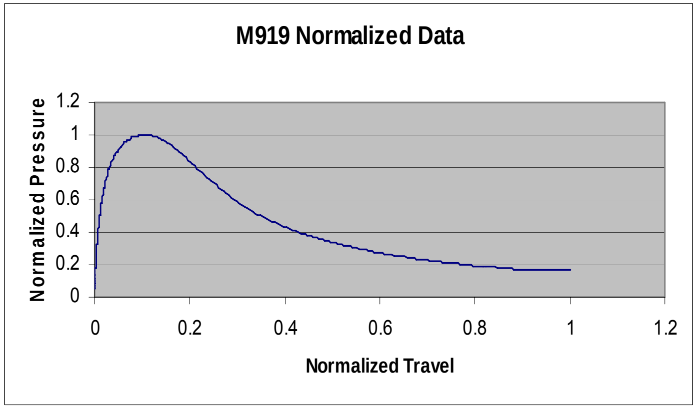
- $$\text{Mean Base Pressure} * \text{Travel} = \frac{\text{Muzzle Energy}}{(\text{Area} * \text{Travel})}$$

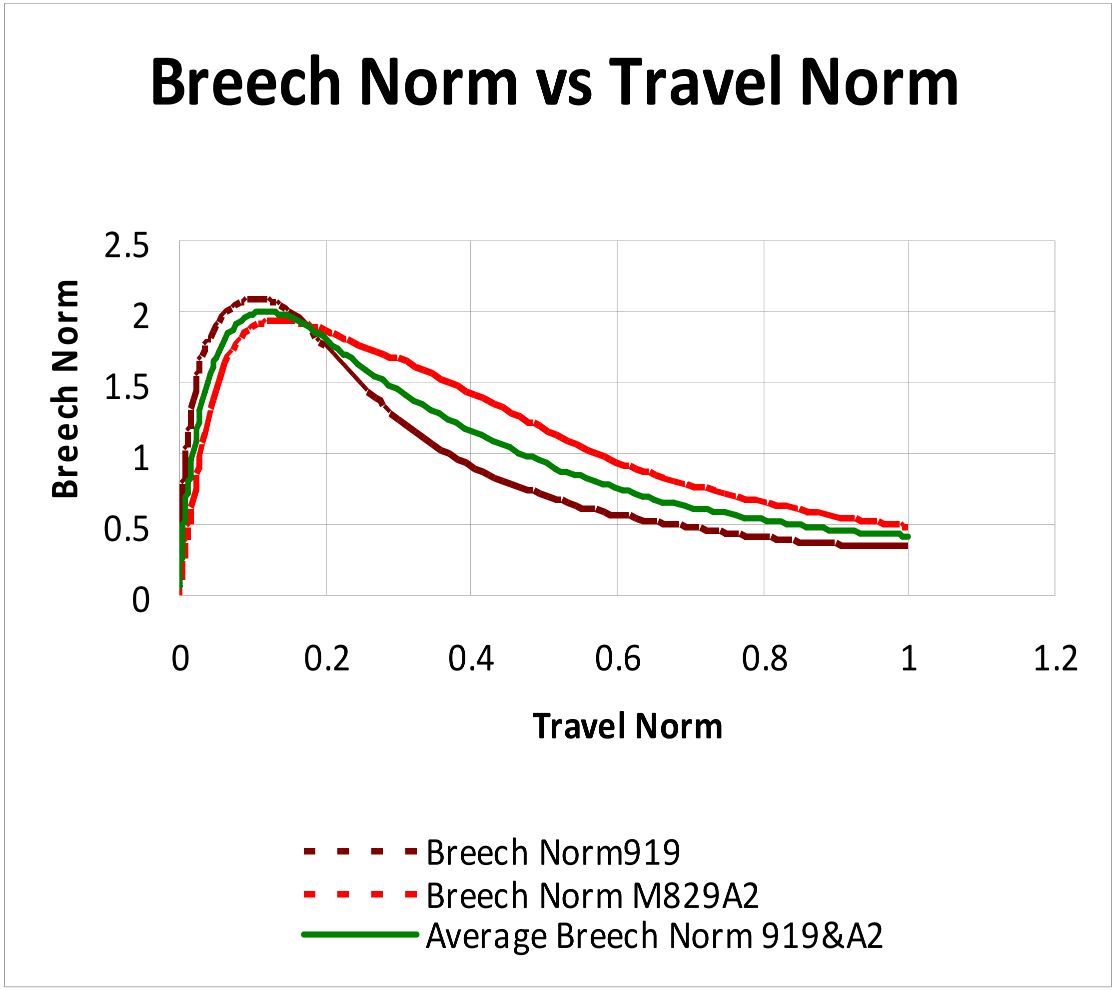
- Breech pressure can then be calculated, since it is on the order of 2/3rd breech pressure (no Lagrange here; no IB code used)

- Factor in energy losses (projectile kinetic energy about 29% of chemical energy)

Pressurization Model







Tube pressurization data generated from the average of normalized breech pressures

Optimization Scheme

Optimization Routine Structure

Design Variable Constraints:

- Projectile Length constraints (penetration cannot exceed 1.2 times length)
- Projectile length to Diameter constraints (5 <≤ LD ≤15)
- Gun Tube length constraint (set by practical restrictions)
- Tube outer diameter constraint (set by practical restrictions)
- Tube muzzle diameter constraint (set by practical restrictions)

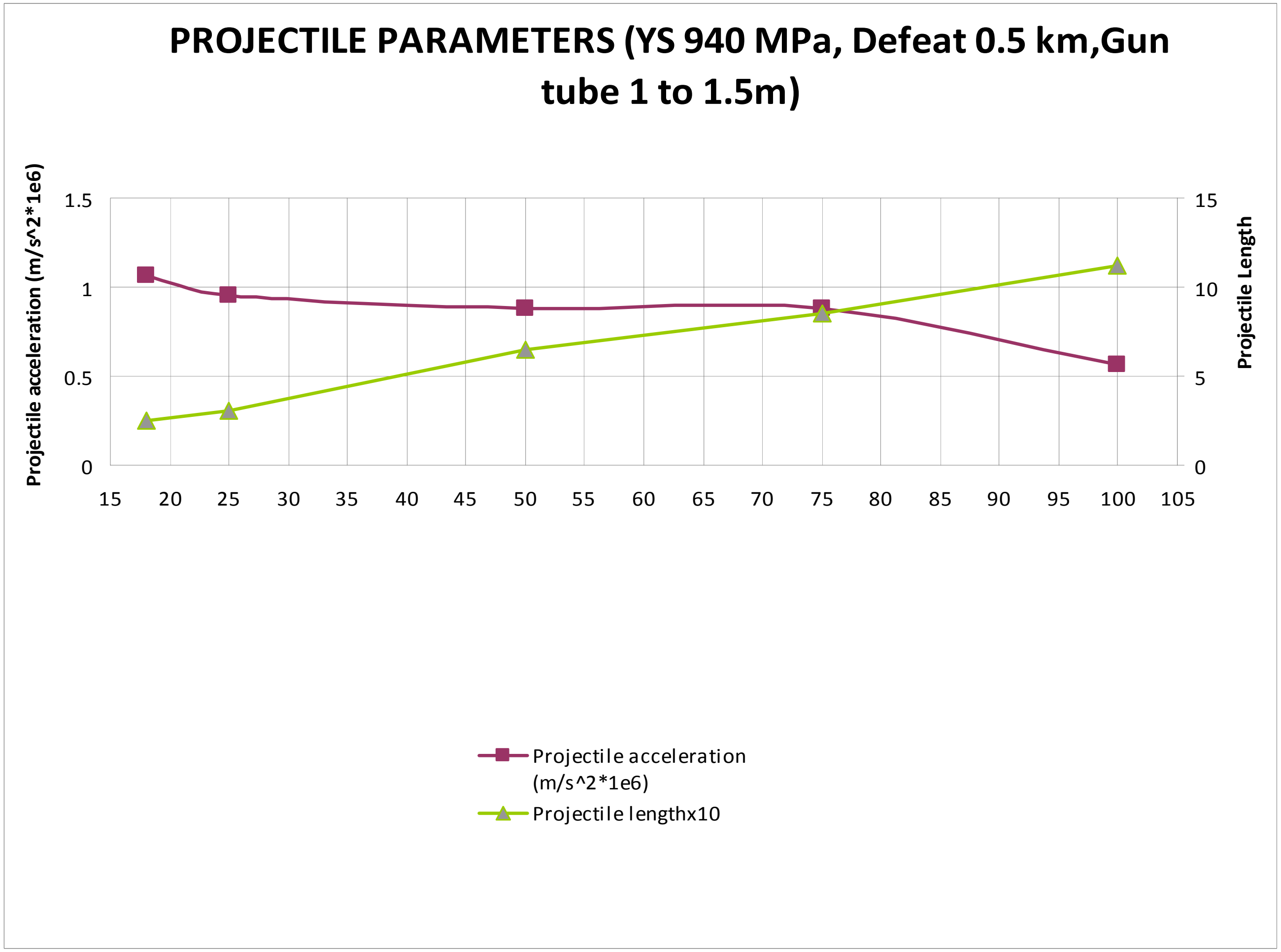
State Variables Constraints:

- Projectile axial stress at base not to exceed
- Projectile von mises stress not to exceed
- von Mises stress at Chamber area not to exceed limit
- von Mises stress at Muzzle area not to exceed limit

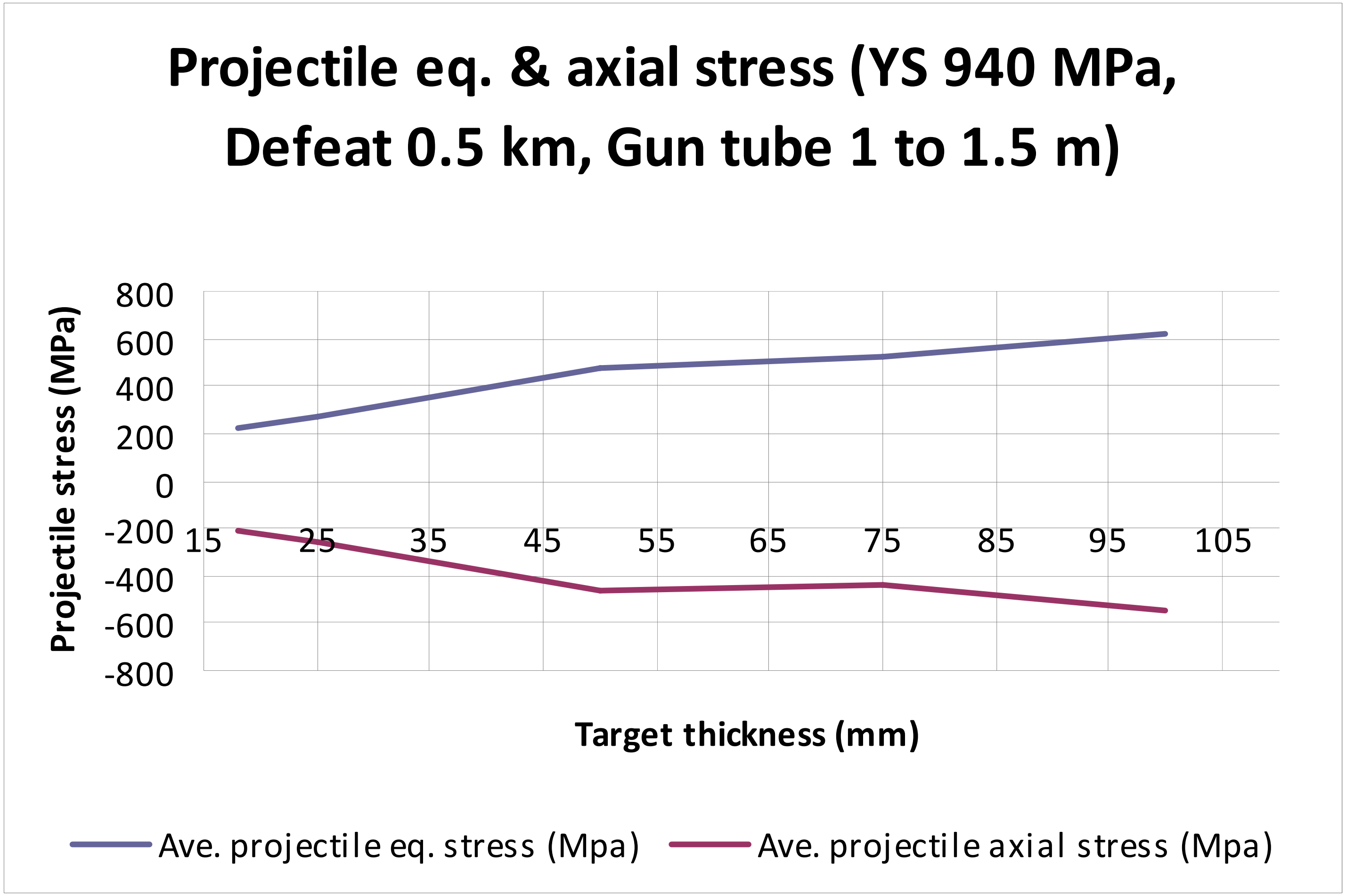
OBJECTIVE Function:

- Minimize Volume of Gun Tube (or weight of tube)

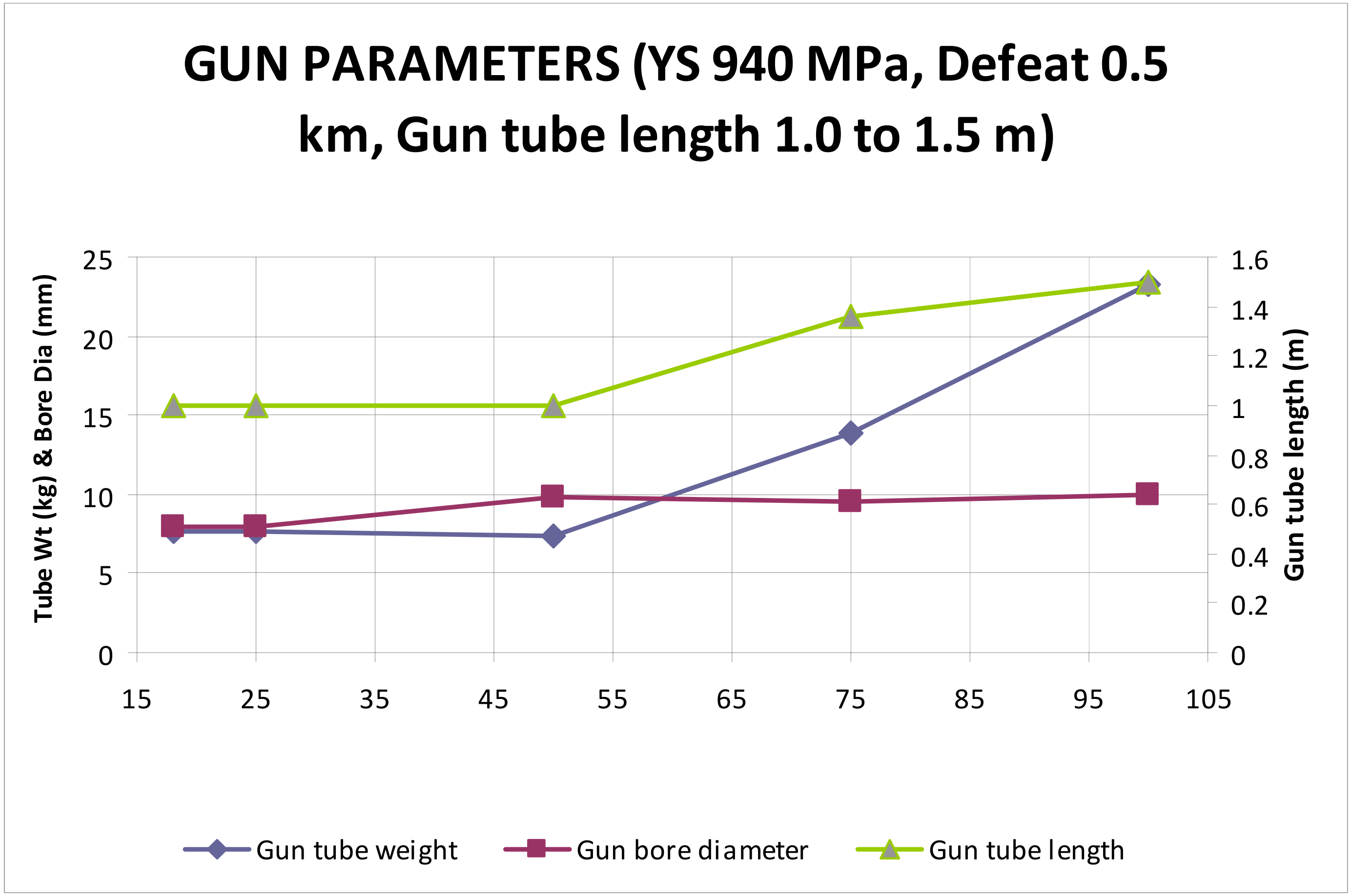
Sample Results



Sample Results



Sample Results



Summary

- A simple model of projectile and gun in an optimization framework has been used to arrive at a first order estimate of the armament system
- Future attempts will be focused adding more features to the projectile and gun model to observe if the approach is still feasible for exploring new armament systems

Advances in Non-Metallic Materials

V C F Hillyard, Ensinger

Kim L Reddick, Ensinger

A Little History

- 1930-1960's, Crystalline resins ruled
- PE, PP, POM,PA,,,,,,,PI, PMMA
- 1960-82, Amorphous resin developed
- PC, PET, PEI, PES, PS, PPS
- 1983, Peek arrives........
- 1990's, Development of filler systems
- 2000+, Hybrid, Blending & Amalgams

“T” Series

- Blend of Thermoplastic/Thermoset
- Fabricates as a pure Thermoplastic
- Mechanical Props from -65 to 600 F
- Chemical Resistance
- Tribological properties
- Flammability and Toxicity
- TDS_T_series_TU60\TDS_T_series_TF60C.pdf
- TDS_T_series_TU60\TDS_T_series_TF60V.pdf
- TDS_T_series_TU60\TDS_T_series_TL60.pdf
- TDS_T_series_TU60\TDS_T_series_TU60.pdf
- TDS_T_series_TU60\TSeriesBrochure_en.pdf

ENSINGER

Nano/Ceramic Additives

- Nano -Re-enforcement & Electrical
- Ceramic -Wear, Re-enforcement, Form
- Blending/Consistency/Stability Issues
- Nano -Armor, Electrical Shielding, ESD
- Ceramic - Bearings/Bushings, Armor

ENSINGER

Thermoplastic composites

- Choice of Thermoplastic Matrix
- Near net shapes, cost effective
- Lightweight structural components
- Ballistic protection
- Electronic shielding
- Accoustic / Vibration dampening

Self Re-Inforcing Polymer (SRP)

- Non Filled Resin
- Compression St similar to Aluminum
- Ablative
- Hardness
- Chemically inert
- Fabrication by most standard methods

Development and Fielding of the Guided Multiple Launch Rocket System (GMLRS) Unitary Warhead

44th Annual NDIA Gun & Missile Systems Conference

April 6 – 9, 2009
Kansas City, MO

Renita Friese – General Dynamics Ordnance & Tactical Systems
Tracey Westmoreland – Lockheed Martin Missiles & Fire Control

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GMLRS Unitary Team

- Prime Contractor – Lockheed Martin Missiles & Fire Control
- General Dynamics – Ordnance & Tactical Systems
- Aviation & Missile Research, Development, & Engineering Center
- Program Executive Office – Missiles & Space
- Precision Fires Rocket & Missile Systems Project Office

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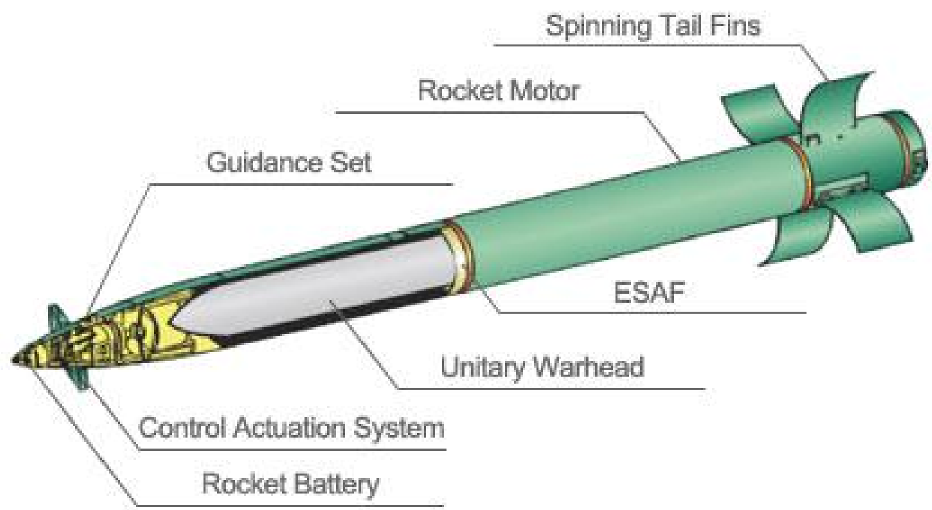
GMLRS Unitary System Description

- Joint Expeditionary
- All Weather, Precision Guided Rocket
- 70km Range
- 196 lb Unitary Warhead
- Tri-Mode Fuze
- Low Collateral Damage
- Target Sets
  - ↗ Buildings
  - ↗ Soft Targets
  - ↗ Urban Structures
  - ↗ Air Defense Surface Targets



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GMLRS in Theatre

- As of 17 February 2009, 1109 Rockets Fired in Theater
- 100% Mission Success
- "70 Kilometer Sniper Rifle"

GMLRS Unitary in Iraq

Past, Present & Future

1980 — 1998 — 2004 — 2005 — 2008

EVOLUTIONARY — REVOLUTIONARY

	Basic Rocket (M26)	Extended Range Rocket (M26A1 / A2)	Guided Rocket DPICM (M30)	Guided Unitary Rocket-UMR (XM31)	Guided Unitary Rocket (XM31E1)
User Requirements					
• Range	32 km	45 km	70 km	70 km	70 km
• Precision / Accuracy	Free Flight Rocket	No Load Detent	Inertial Measurement Unit (IMU) / Global Positioning System (GPS) Aided	IMU / GPS Aided	IMU / GPS Aided
• Flexibility	—	Deeper Targets Farther Laterally "General Support (GS)" Mission	Deeper Targets Farther Laterally "GS-Reinforcing" Mission	Deeper Targets Farther Laterally "GS-Reinforcing" Mission	Deeper Targets Farther Laterally "GS-Reinforcing" Mission
• Payload	644 Dual Purpose Improved Conventional Munition (DPICM) M77 Grenades	518 DPICM M77 Grenades	404 DPICM M101 Grenades	Unitary with Dual Mode Fuze	Unitary with Multi-Option (Tri-Mode) Fuze
• Maneuver Safety	5% Dud Rate	4% Dud Rate / < 1% with M101	Threshold: < 2 / 4% Dud Rate Objective: 0% Dud Rate	NA	NA
• Targets	Soft	Soft	Soft	Hard Stationary Point Targets Collateral Damage Sensitive Soft Area Targets	Hard Stationary Point Targets Collateral Damage Sensitive Soft Area Targets

Warhead

- Evolved from 6-inch to 3-inch Fuze Design
- Internal Scored Case to Control Fragmentation to Minimize Collateral Damage
- Warhead Weight – 196 lbs
- Approximately 50 lbs of High Explosive
- Won Competition in 2006 for Follow-on Production Contract

Modeling & Simulation

- OTI*HULL – GD-OTS Proprietary Hydrocode Software
  - Simulates Weapon Problems from Target Interaction through Functioning
- Also use Hydrocode to Predict Insensitive Munitions (IM) Results
  - Bullet Impact, Fragment Impact, Sympathetic Detonation

Environmental Qualification

- Warhead Passed Environmental Qualification
- Tests:
  - ↗ Vibration
    - Transportation, Tactical, Flight
  - ↗ Temperature Shock
  - ↗ Rail Impact Shock
  - ↗ Handling Drop Shock
  - ↗ Launch Shock
  - ↗ Long-Term Storage

Performance Results - Effectiveness

- Five JMEM Arena Tests Conducted
  - ↗ Fragments Recovered & Weighed
  - ↗ Recovery Locations were Recorded
  - ↗ Fragment Velocities Calculated
- Warhead is Lethal Against Target Set

Performance Results - Penetration

- Earth & Timber Bunker Target
  - ↗ Successfully Penetrated Target During Development Tests

Earth & Timber Bunker Pre-Test Setup

Earth & Timber Bunker Post-Test

Performance Results – Insensitive Munitions

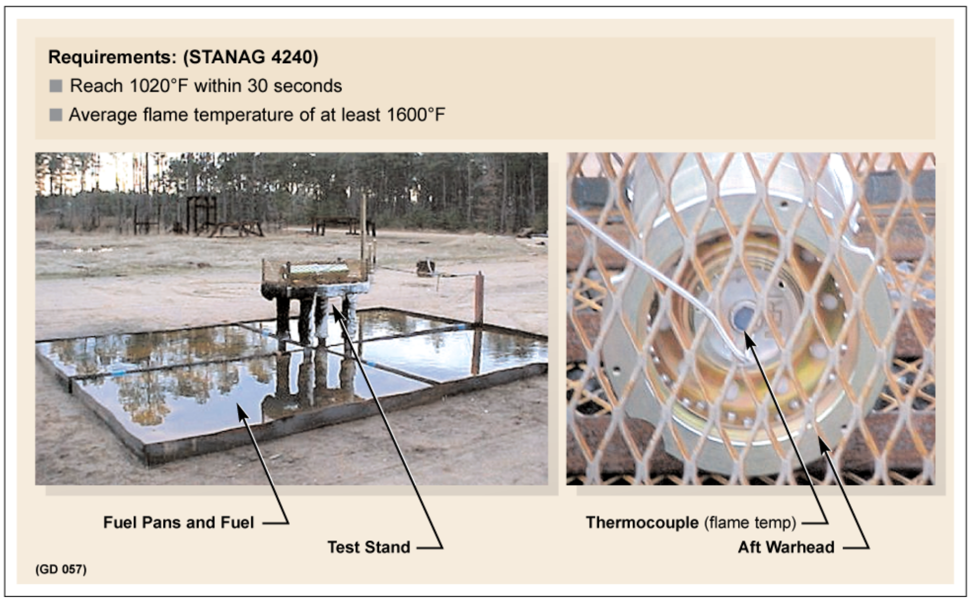
Insensitive Munitions Verification and Investigations	MIL-STD-2105/STANAG Description	Achievable Results Given in STANAG Type Classification
Intermediate Cook-Off	Remote Fire Not in Direct Contact with Warhead: 50°F (10°C) per Hour Heating Rate	Type V (SDD Testing) Type III (Subsequent Testing)
Fast Cook-Off	Flames in Direct Contact with Warhead: Average Flame Temperature ≥ 1600° F (871°C)	Type IV (SDD Testing) Type IV (Subsequent Testing)
Bullet Impact	.50-Caliber Bullet Fired into Payload Section of Explosive	Type V (SDD Testing) Type V (Subsequent Testing)
Fragment Impact	Land-Attack Threats: 16.2 gram Steel Fragment Impacts Munition at 6000 ft/s	Type V (Subsequent Testing)
Sympathetic Detonation	Propagation of Detonation from One Payload Section to Another	Type I (Subsequent Testing)

Intermediate Cook-Off Test

- Test Conducted IAW STANAG 4382 – Slow Heating Test for Munitions
- Enclosed in Oven Housing
- Ramp Rate 50ºF/hr
- Blast Gauges and Witness Plates Showed no Evidence of Detonation

Fast Cook-Off Test

- Test Conducted IAW STANAG 4240 - Liquid Fuel Fire Tests for Munitions
- Approximately 1000 Gallons Kerosene in Fuel Pans
- Internal Warhead Components Expelled from Case



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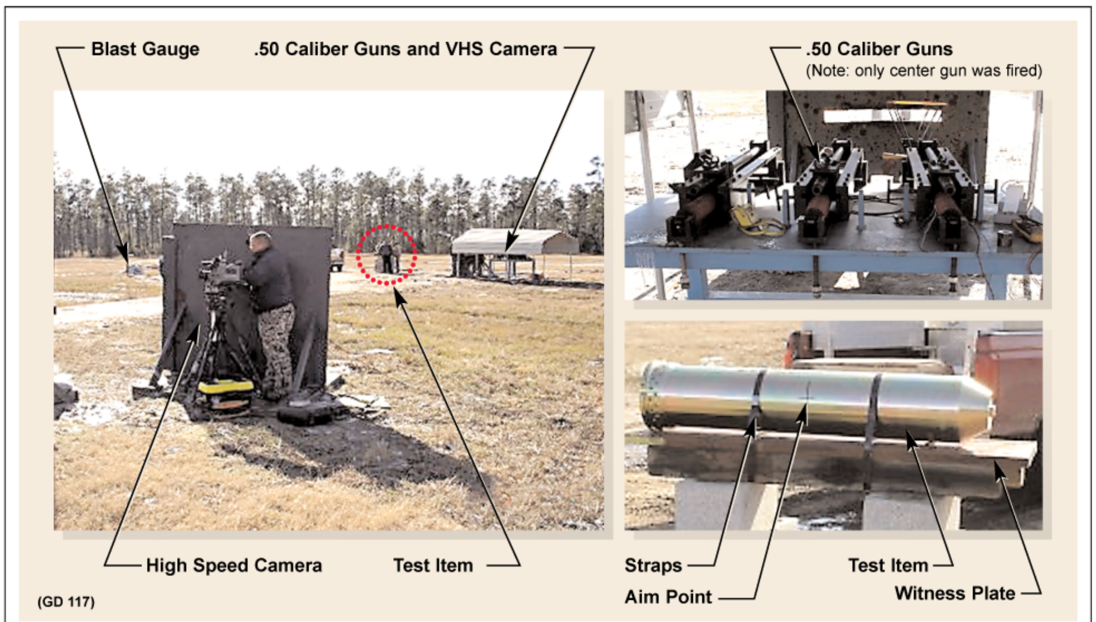
IM Testing – Bullet Impact

- Test Conducted IAW STANAG 4241 – Bullet Attack Test for Munitions
- .50 Caliber Type M2 Armor Piercing Projectile
  - 2840 ft/sec
- Aim Point – Center of Warhead
- No Exit Bullet Hole
- Blast Gauges and Witness Plates Showed no Evidence of Detonation



GMLRS Warhead Performance

Requirements	Performance
Effectiveness	Warhead Lethal Against Target Set
Penetration	Warhead Penetrates Earth & Timber Bunker Target
Insensitive Munitions (IM)	● Type V – Bullet Impact ● Type IV – Fast Cook-Off ● Type III – Intermediate Cook-Off ● Type I – Sympathetic Detonation ● Type V – Fragment Impact

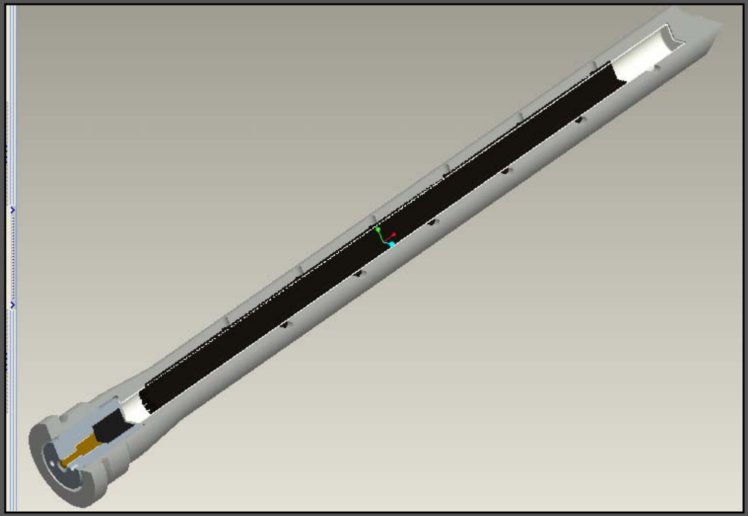
Design Challenges

- Insensitive Munitions
  - Passing Fast and Slow Cook-Off Proved to be a Challenge
    - Pressure Built up in Warhead Nose
    - Warhead Case Structural Integrity did not Allow Venting in Nose

Acknowledgements

- COL David Rice, Precision Fires Rocket and Missiles Systems Project Manager
- LTC Mark Pincoski, Precision Guided Rockets/Missiles Product Manager
- Darren McConnell, Deputy Product Manager for GMLRS
- Larry Grater, System Engineer Principal
- Tracey Westmoreland, Mechanical Engineer Staff

HERO Compliant Electric Primer for Tank Ammunition



Presented by:

Jason Mishock

8 April 2009

Malcolm Baldrige National Quality Award 2007 Award Recipient

 TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Background for the Need for a HERO Safe Primer

- Definition:

  HERO (Hazards of Electromagnetic Radiation to Ordnance)

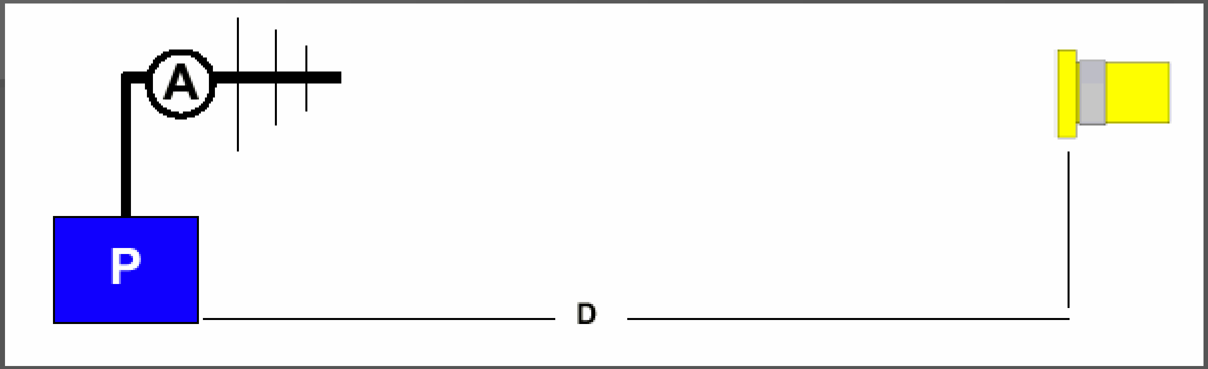
- Primer testing was conducted to ensure that the radios used on the M1A1/A2 SEP Abrams tank platforms were compatible with the 120mm main gun ammunition.

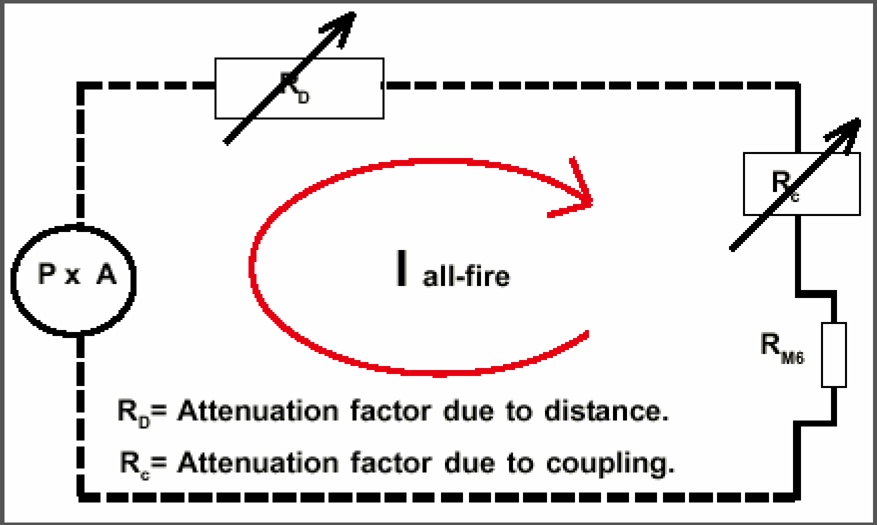
- Test results showed that the current primer did not have an issue with the current tank configuration but still did not meet the HERO requirements.

- Ammunition currently does not meet the MIL-STD-464A for HERO compliance. This restricts the handling of the ammunition while outside its packaging container when in certain RF (Radio Frequency) conditions. One example is during shipment on Naval ships.

Basic Electromagnetic Theory

Maximum human body absorption of RF energy is from 40MHZ - 90MHz



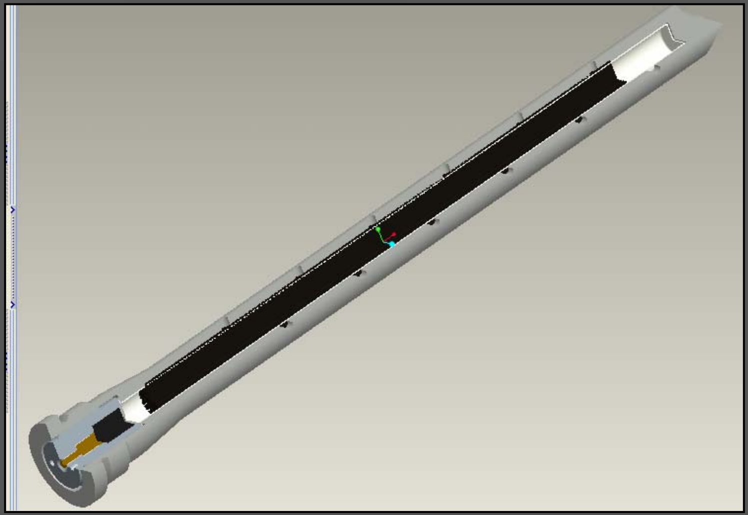


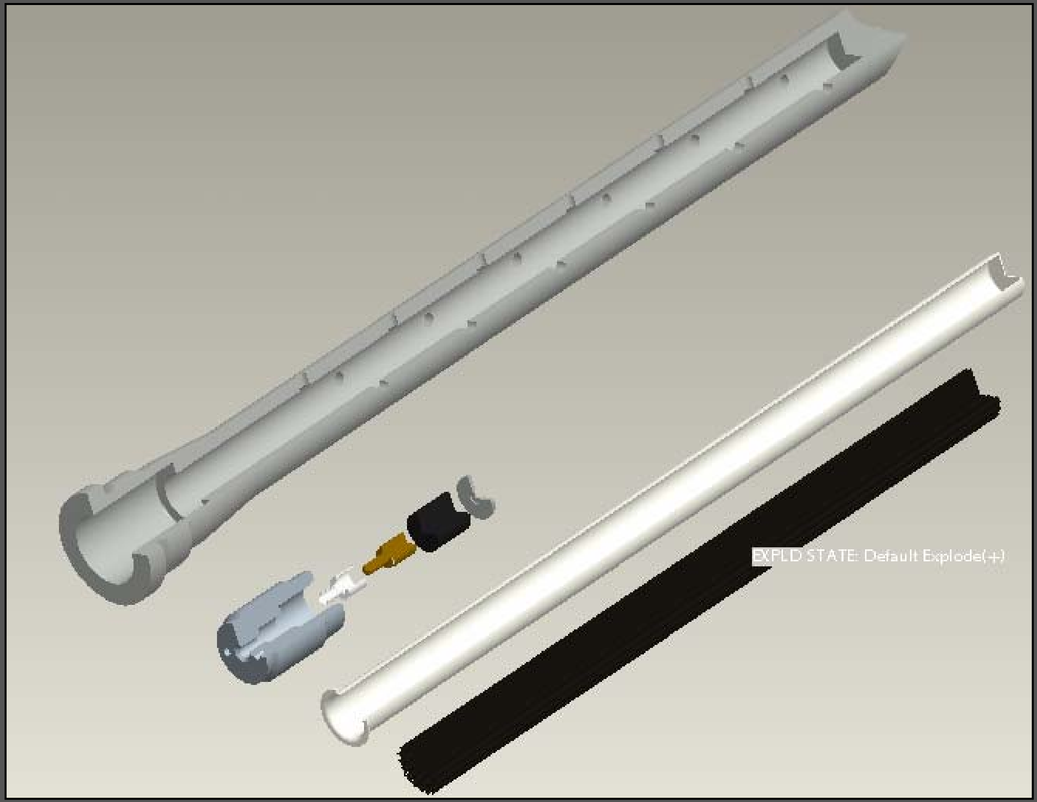
Problem Statement

- Current P/N 12525143 thick wall primer's ignition element is not HERO compliant
- Current primer has several features that can lead to critical defects in manufacturing
- Current primer is very labor intensive to build
- Purple lacquer for sealing the flash hole may not be available in the near future

The M125 Thickwall Primer has many critical characteristics and is difficult to manufacture

The improved Thickwall Primer eliminates most critical characteristics and is easier to manufacture

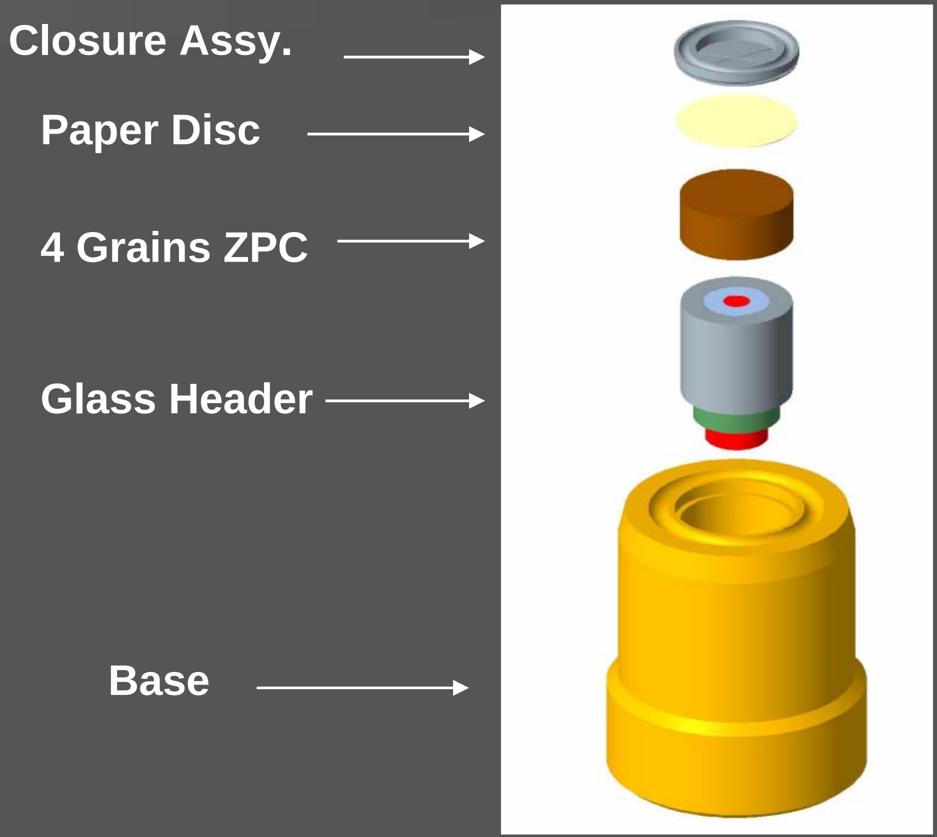




HERO Safe Primer

Simple

- Fewer parts
- Reduced labor
- Lower cost for ignition element
- Less to go wrong in manufacturing



HERO Safe Primer

Compatible

- **One igniter design for all tank ammunition primers**
  - Primer, Electric (current development)
  - M129 (future development)
  - M123A1 (future development)

System Requirements

- Must meet HERO requirement per MIL-STD 464A
- Must meet ESD requirements per MIL-STD 331C, subtest F1
- Must meet 120mm International Control Document (ICD) requirements
- Must meet fire control on M1A1/A2 Abrams tanks
  - Must be compatible with Blasting machine
- No degradation in ballistic performance
- Minimize cost increase over the current design

Primer Ignition Train Redesign Concepts

<u>Glass to metal header</u>

- Electrode is molded with a glass insulator that is pressed into igniter element base with a welded bridge wire making a more robust design
- Ignition mix is environmentally friendly – ZPC (Zirconium Potassium Chlorate)
- Meets initial HERO requirements
- Meets initial ESD requirements
- Meets system requirements for both US and international standards (ICD)
- Met cost requirements – currently will be less costly than current design
  - –Note: One piece body design for the M125 primer will increase cost
- Current ballistic requirements
  - –Cold condition is up to 5 ms slower than controls

Current Primer vs. Redesign Primer

Current primer data
- No fire 210 mA
- All fire 1.25 Amps
- Paper and lacquer seal for primer tube
- Three piece body design

Initial primer redesign data
- No fire 1.12 amps
- All fire 2.18 amps
- Plastic liner seal for primer tube
- One piece body design

Future Schedule

- Phase 1-3 (completed)
- Phase 4 – Finalize design and verification testing – estimated completion date – August 2009
- Qualification testing – estimated completion date – 31 December 2009

IM Design Constraints for the LRLAP Warhead

NDIA Conference

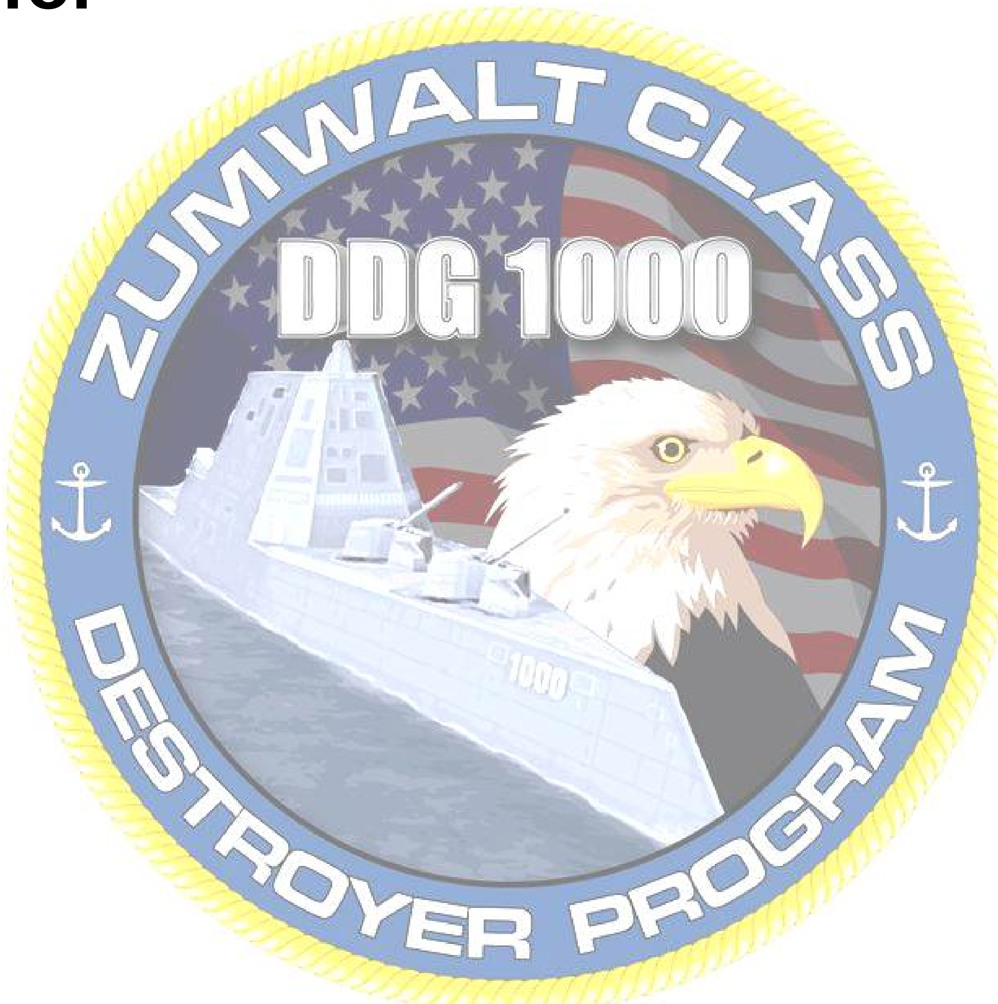
April 2009

Tyrus S. Burford

General Dynamics- Ordnance and Tactical Systems

Aaron Warriner

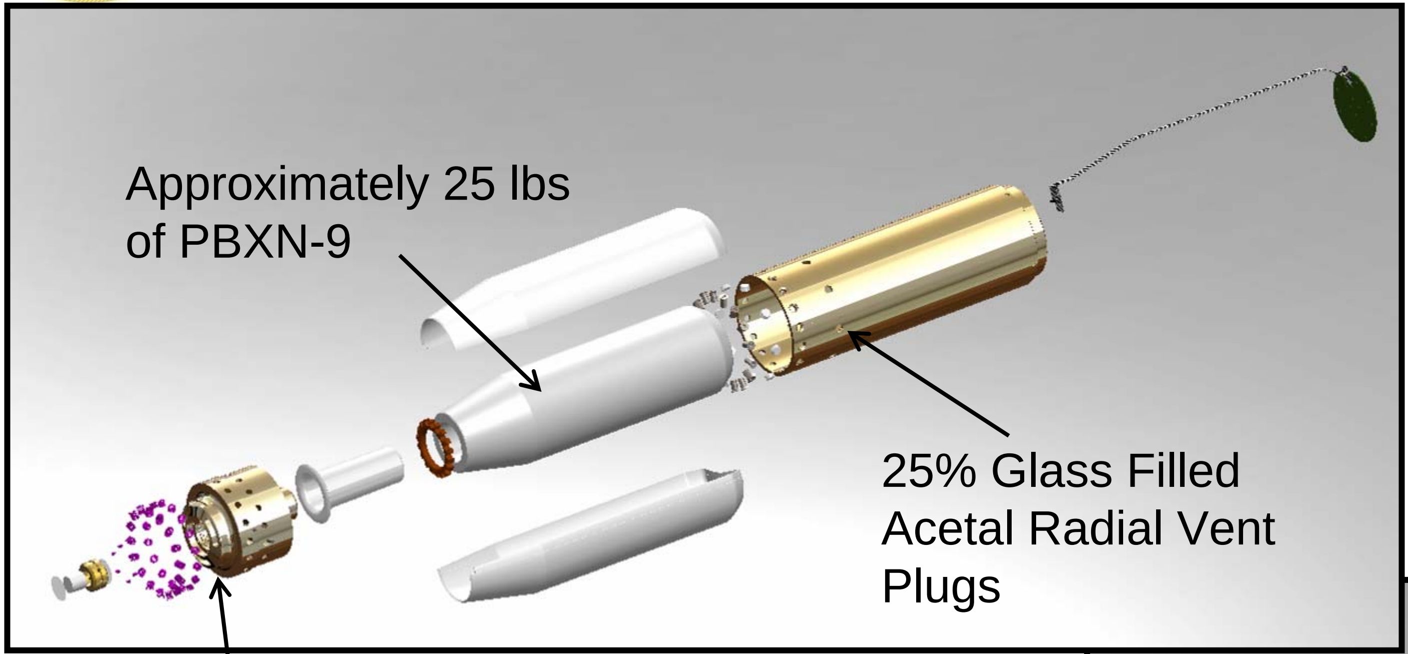
Lockheed Martin Missiles and Fire Control



Overview

- Design Overview
  - Thermal Requirements
- LRLAP Warhead Design Evolution
- Thermal Analyses
- IM Tests

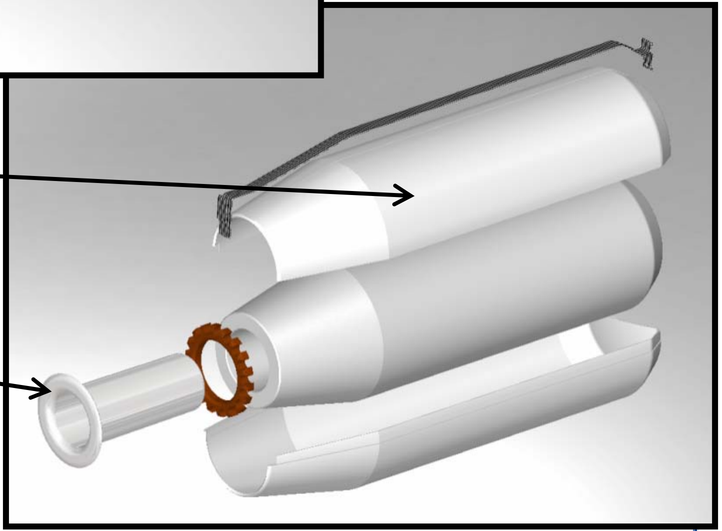
LRLAP Warhead Design



Venting Slots in Forward Closure

Two Piece Acetal Liner

High Density Polyethylene Top

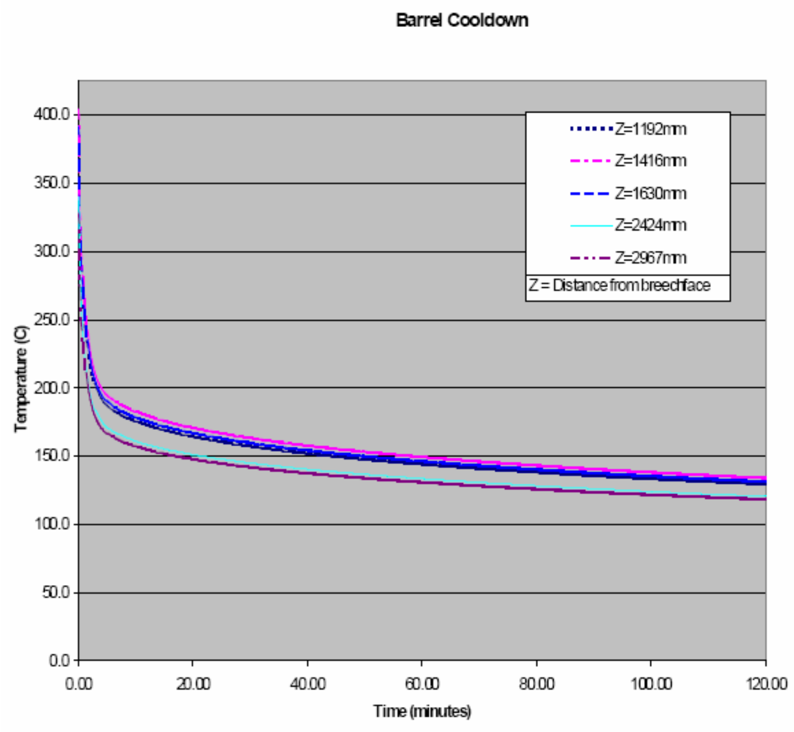


IM Design Evolution

- Preliminary Warhead Design
  - Problem Statement
    - Bounding the problem
  - Four piece liner design, HDPE and PEEK
  - Hot Gun Analysis
  - Hot Gun Test
  - Fast and Slow Cook-off Tests
- IM Design Changes
  - Hot Gun Analysis
  - Fast and Slow Cook-off Tests

Thermal Requirements

- Gun Launched Projectile subject to gun barrel cooling curve for time duration during firing



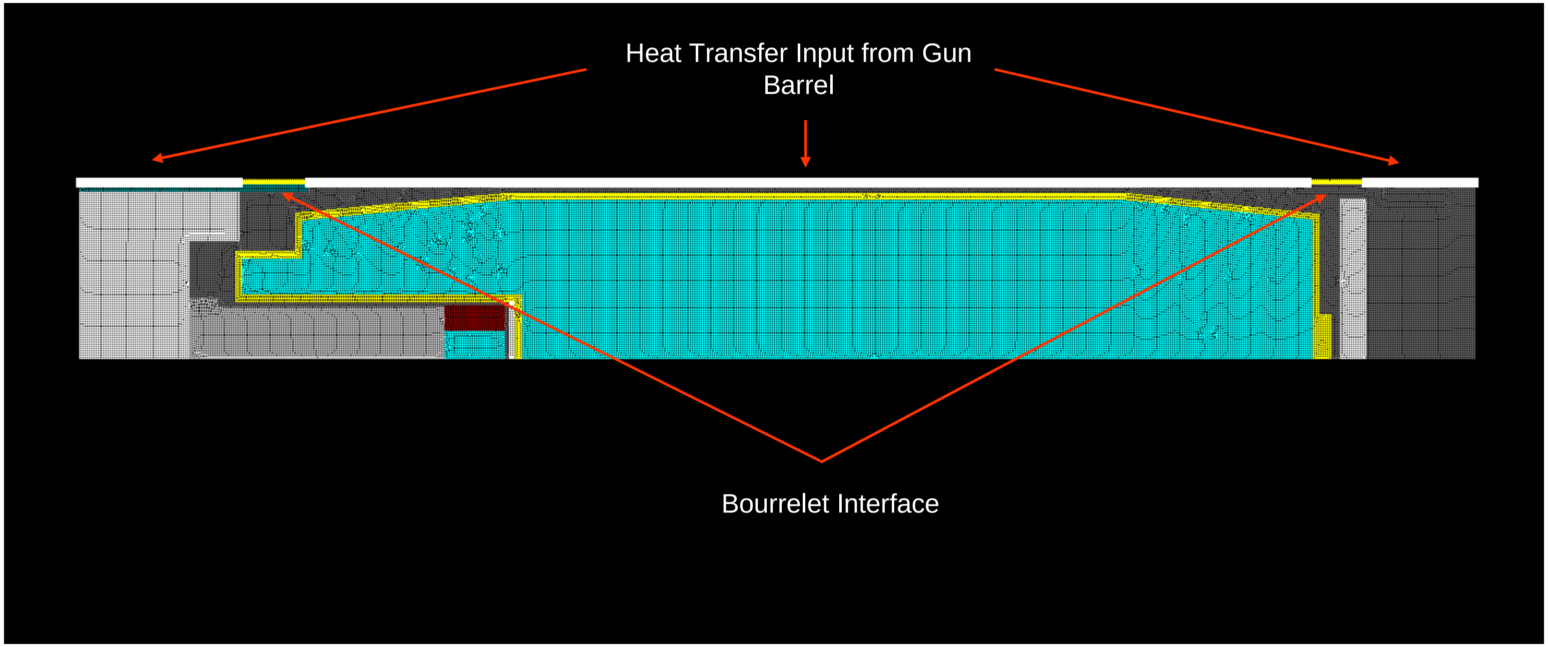
- Must have a Type V reaction for fast cook-off and slow cook-off (6°F/hr heat rate)

IM Problem Statement

- The LRLAP warhead needed to be design in order to meet two conflicting design requirements
  - An insensitive munitions liner was needed that would melt during a thermal event, such as fast and slow cook-off
  - The warhead needed to insulate the explosive such that sitting inside of a hot gun barrel for a two hour duration would not cause an adverse reaction
- How do we design an IM feature that melts for fast and slow cook-off but is thermally stable throughout the long duration Hot Gun environment?

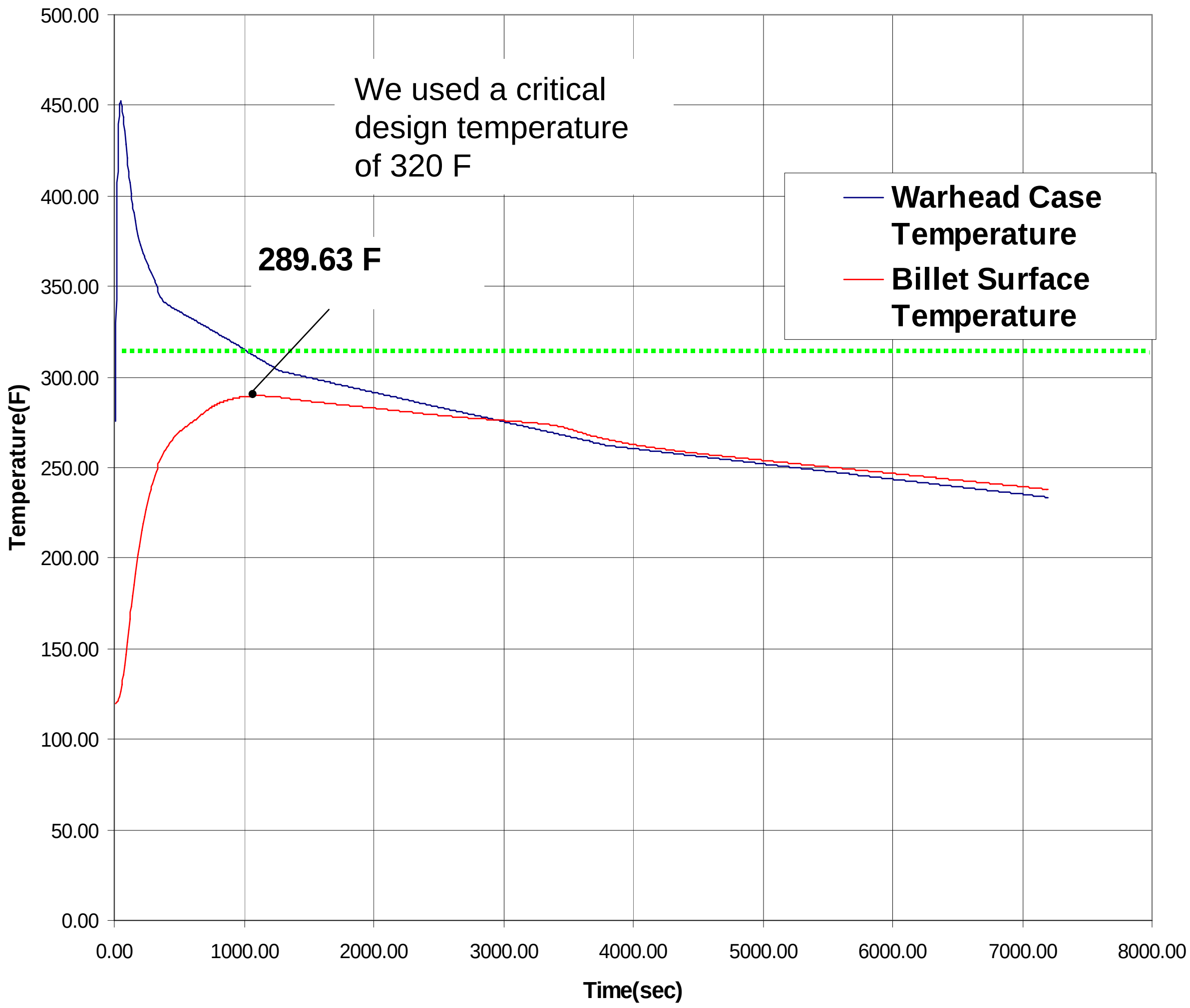
Preliminary Hot Gun Analysis

- Element plot shows different material properties used in analysis
- Boundary conditions used were convection and radiation
- High convection used at Bourrellets rather than conduction to simulate a more accurate boundary condition.



Preliminary Hot Gun Analysis

The temperature was recorded at the inner surface of the warhead case and the outer surface of the billet at nodes in the center of the warhead.

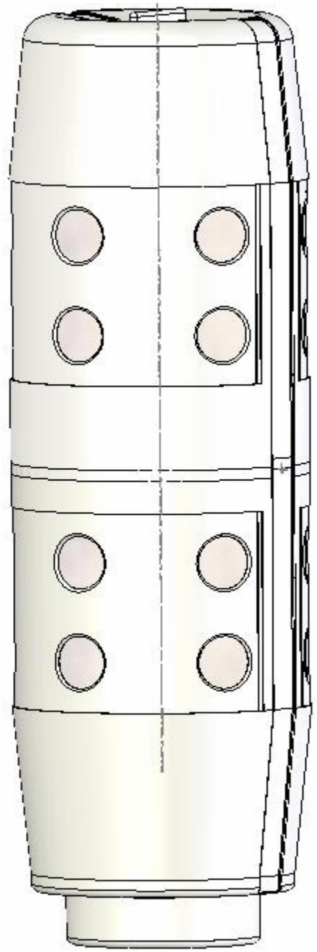


AGS Long Duratiuon Hot Gun Analysis With Grooved Thermal Shield Concept

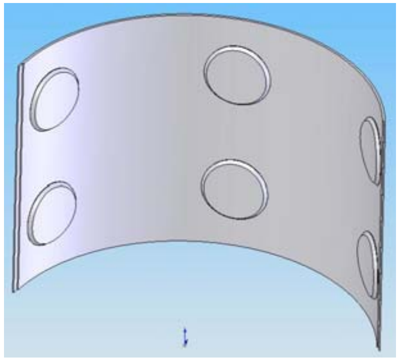
Thermal Analysis

- Analysis showed that the billet needed to be kept at a constant distance from the wall of the warhead case to minimize heat transfer to the explosive
- A high temperature plastic sleeve was designed to give the explosive a constant standoff
- In high production, HDPE could be injection molded around upper and lower sleeve so that billet will be held at a constant distance from the case wall

Two Piece High Density Polyethylene Liner



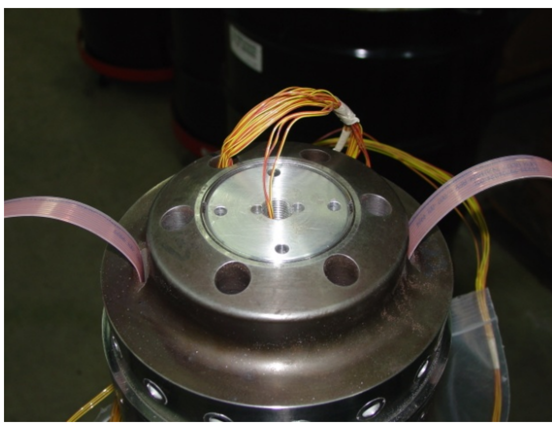
Polyaryletheretherketone (PEEK) Sleeves

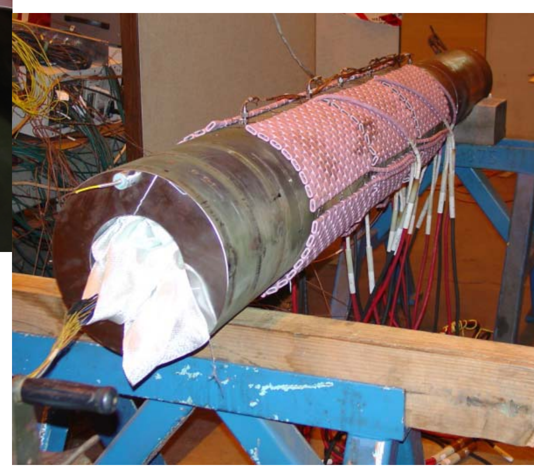


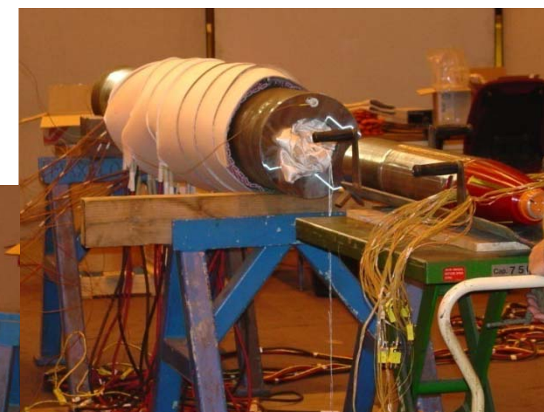
LOCKHEED MARTIN

Hot Gun Test

- Hot Gun Test conducted in September 2004
  - Goal was to simulate the Hot Gun Environment
  - Inert warhead was instrumented with 24 thermocouples and placed inside 9 ft section of a M199 155 mm gun barrel
    - – Thermal blankets used to control heat rate of barrel

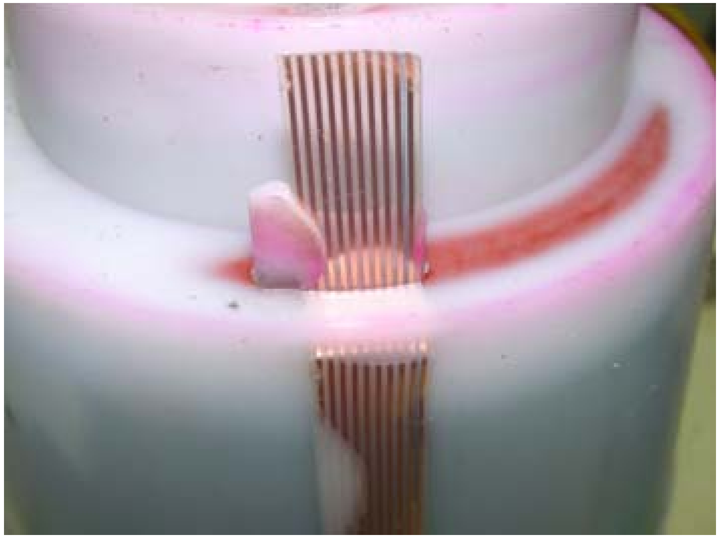


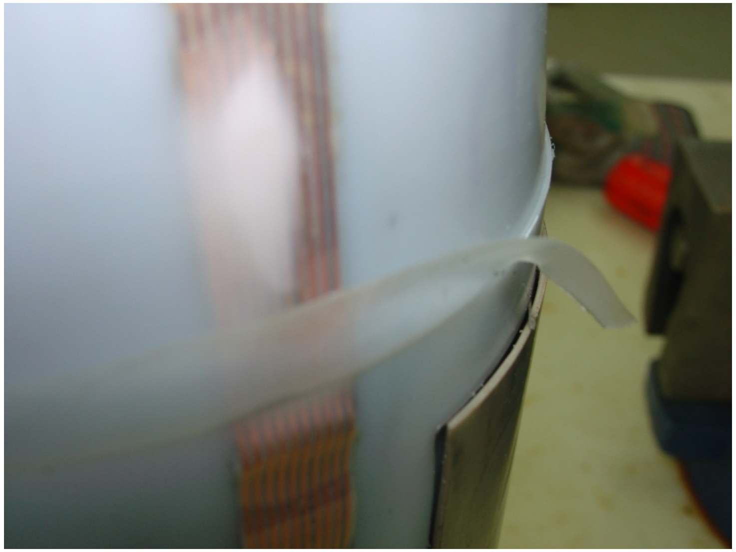




Hot Gun Post Test

- Billet temperature remained below its reaction temperature
  - PEEK sleeves maintained uniform spacing between billet and warhead case
- However, other warhead components became entrapped in melted plastic. This was potential for damage to occur during gun lauch

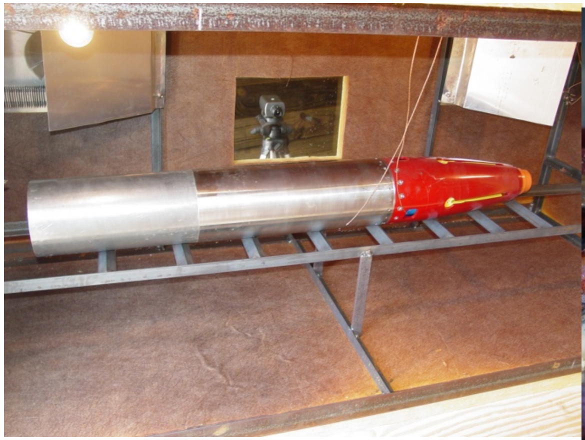


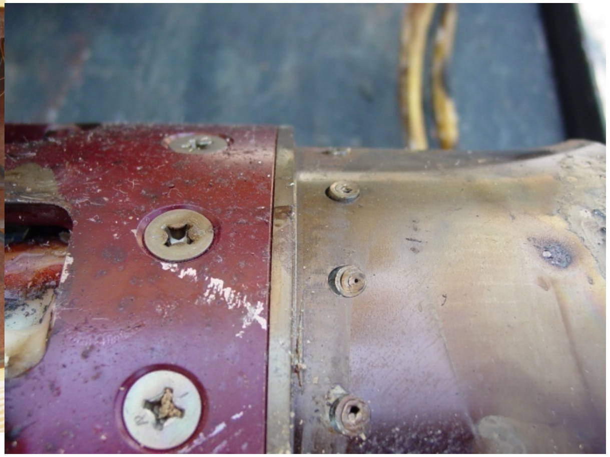


Cook-off Tests

- Fast Cook-off
  - Pressure build up caused pins to shear and free venting to occur
  - Type IV or V reaction

- Slow Cook-off
  - Again pressure caused joint to separate and venting to occur
  - Type IV or V reaction



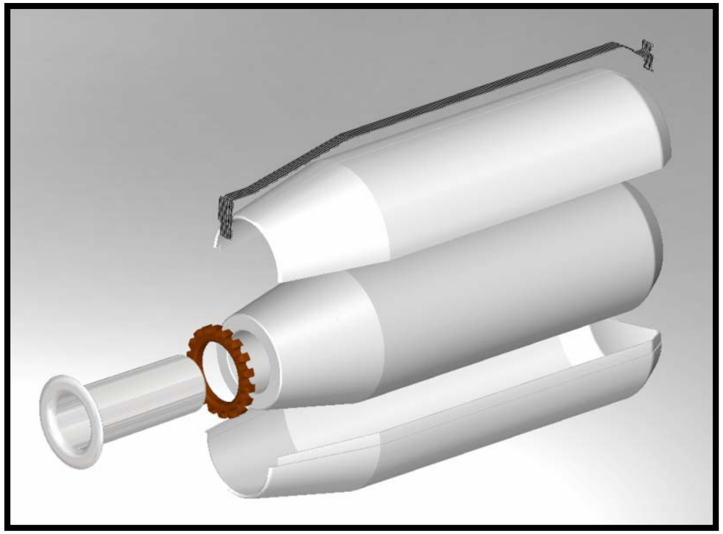


Redesign

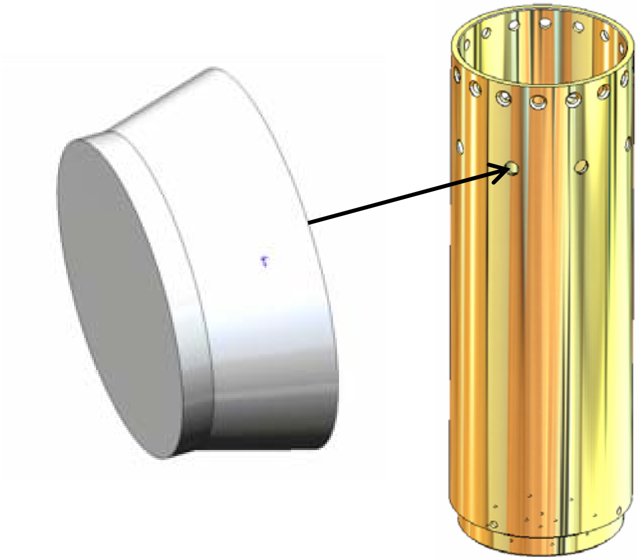
- IM liner was a known design flaw
  - Melting during a Hot Gun environment would not be permissible regardless of keeping explosive temperature low
- Adding to design difficulty, system level design maturity revealed that coiled pin joint design did not provide enough stiffness for flight
  - Threaded fastener joint must be used
    - Would not allow joint shearing to occur during cook-off
    - Needed to add more vent area to reduce pressure

Design Changes

- Solution to Hot Gun Issues
  - IM liner material change
    – Acetal with a 330°F melt temperature

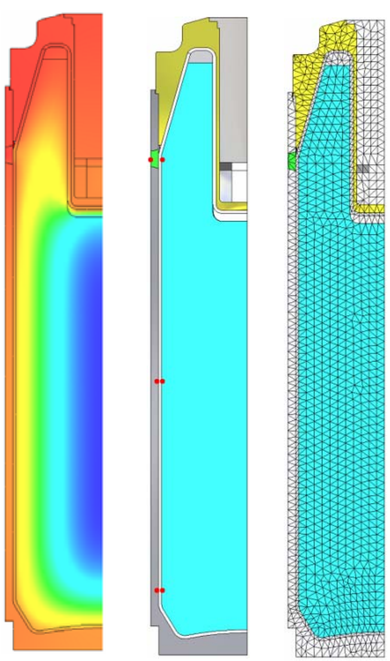


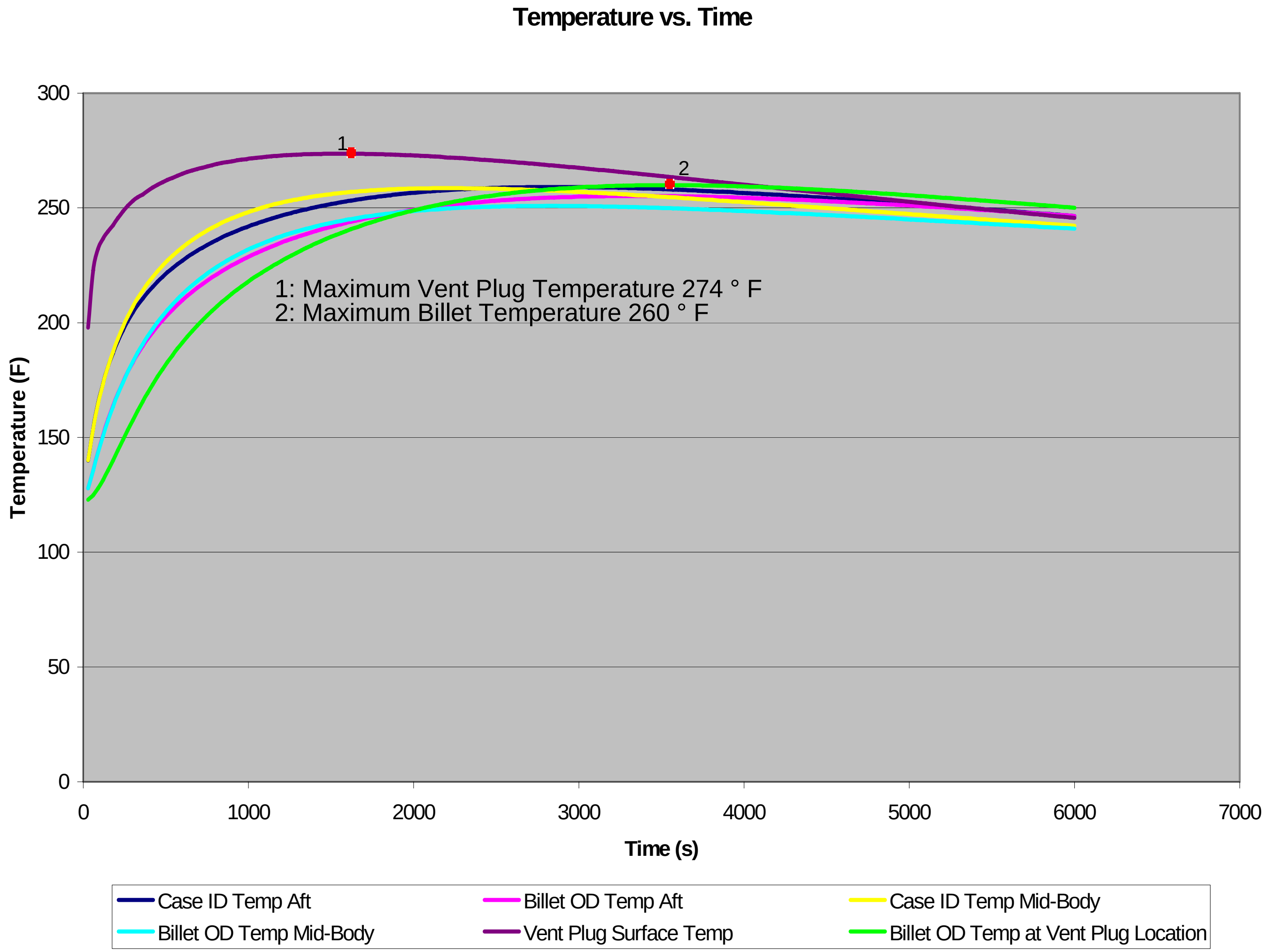
- Solution to Fast and Slow Cook-off Issues
  - Incorporate radial vents into design
    – Vent plugs made from 25% glass filled acetal (glass provides structural rigidity for gun launch)



Hot Gun Analysis- New Design

- Billet remains well below cook-off temperature
- Vent plugs and liner remain below melt temperature





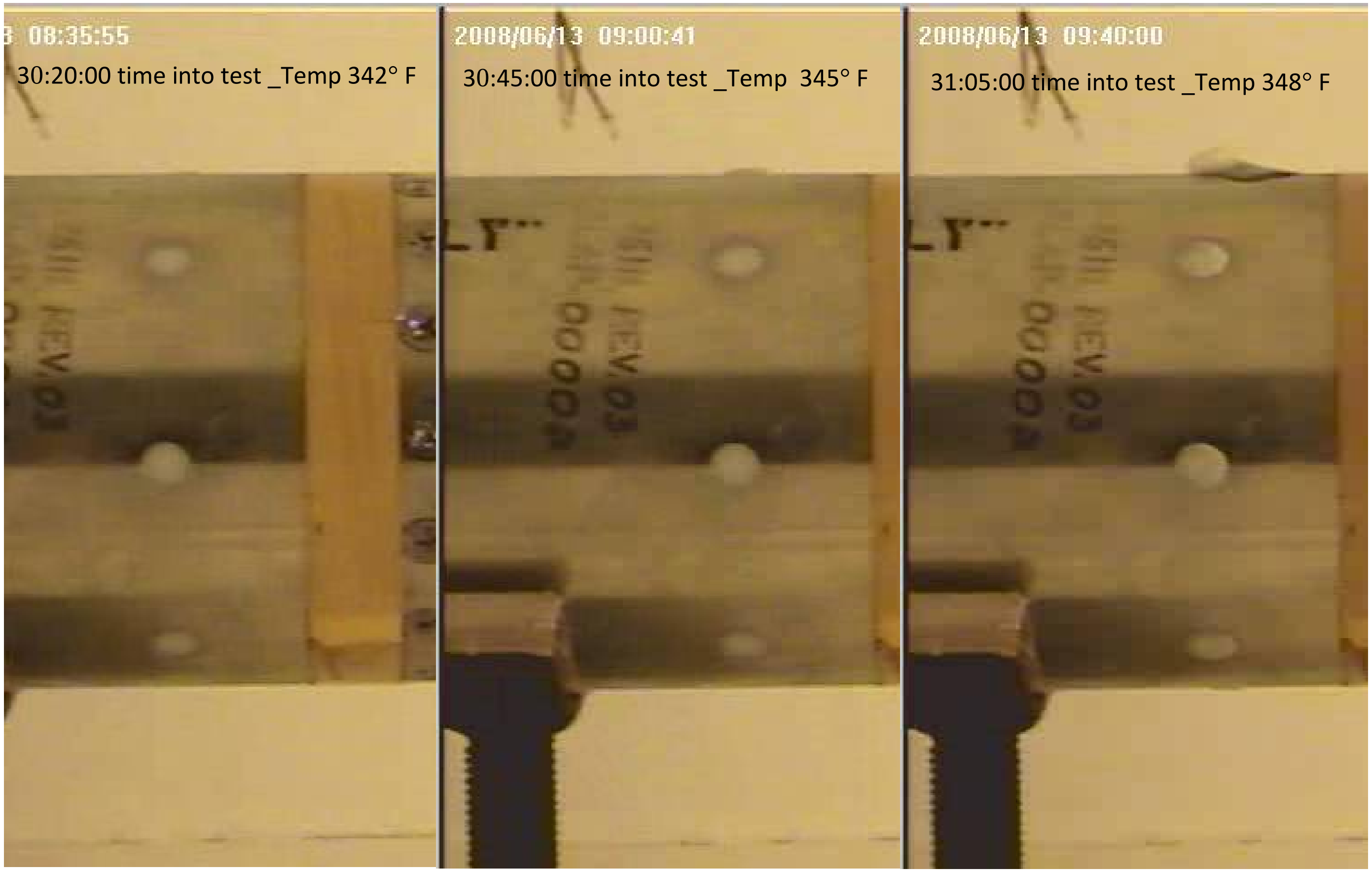
Fast Cook-off Test- New Design

Video Clips

Reaction Considered Type V

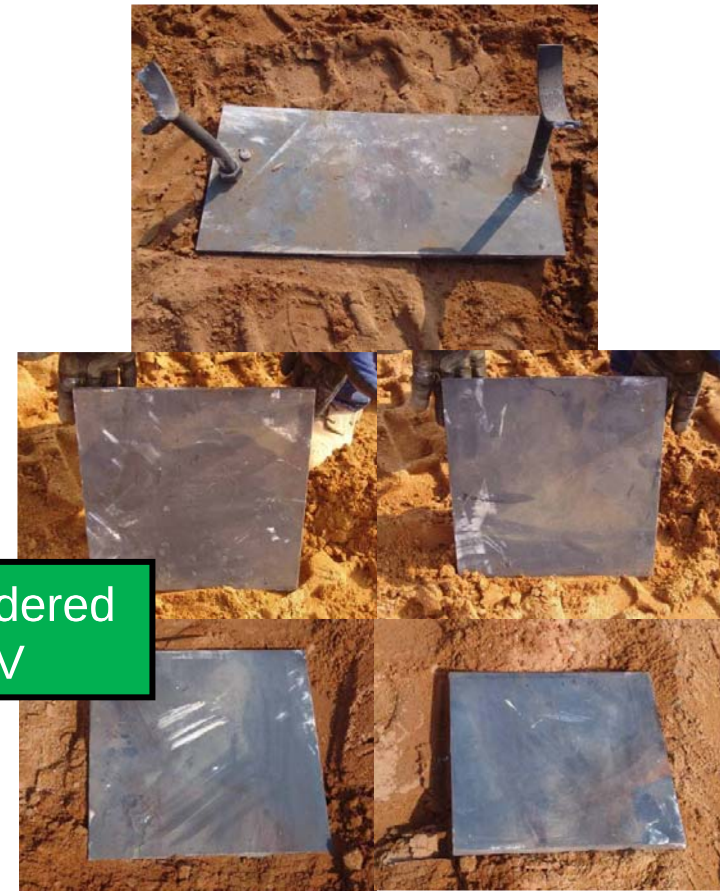
Slow Cook-off Test- New Design

Timeline



Slow Cook-off Test- New Design (Cont'd)

Timeline



Reaction Considered Type IV or V

Shows the possible decomposition of the PBXN-9 elements.

Conclusions

- Initial design was successful at maintaining a constant spacing between warhead billet and case
  - Resulted in thermally stable billet in Hot Gun environment
  - Was not successful at keeping internal components from being encapsulated in the melted IM liner
  - ✓ Solution: Analysis of new liner material indicates that melt temperature will not be reached, thus internal components will survive
- Change to threaded fasteners would no longer allow joint to shear and vent area to increase as pressure increased
  - ✓ Solution: Fast and Slow Cook-off tests reveal Type IV or V reaction is achieved with radial vents

Effectiveness of Air Burst Munitions

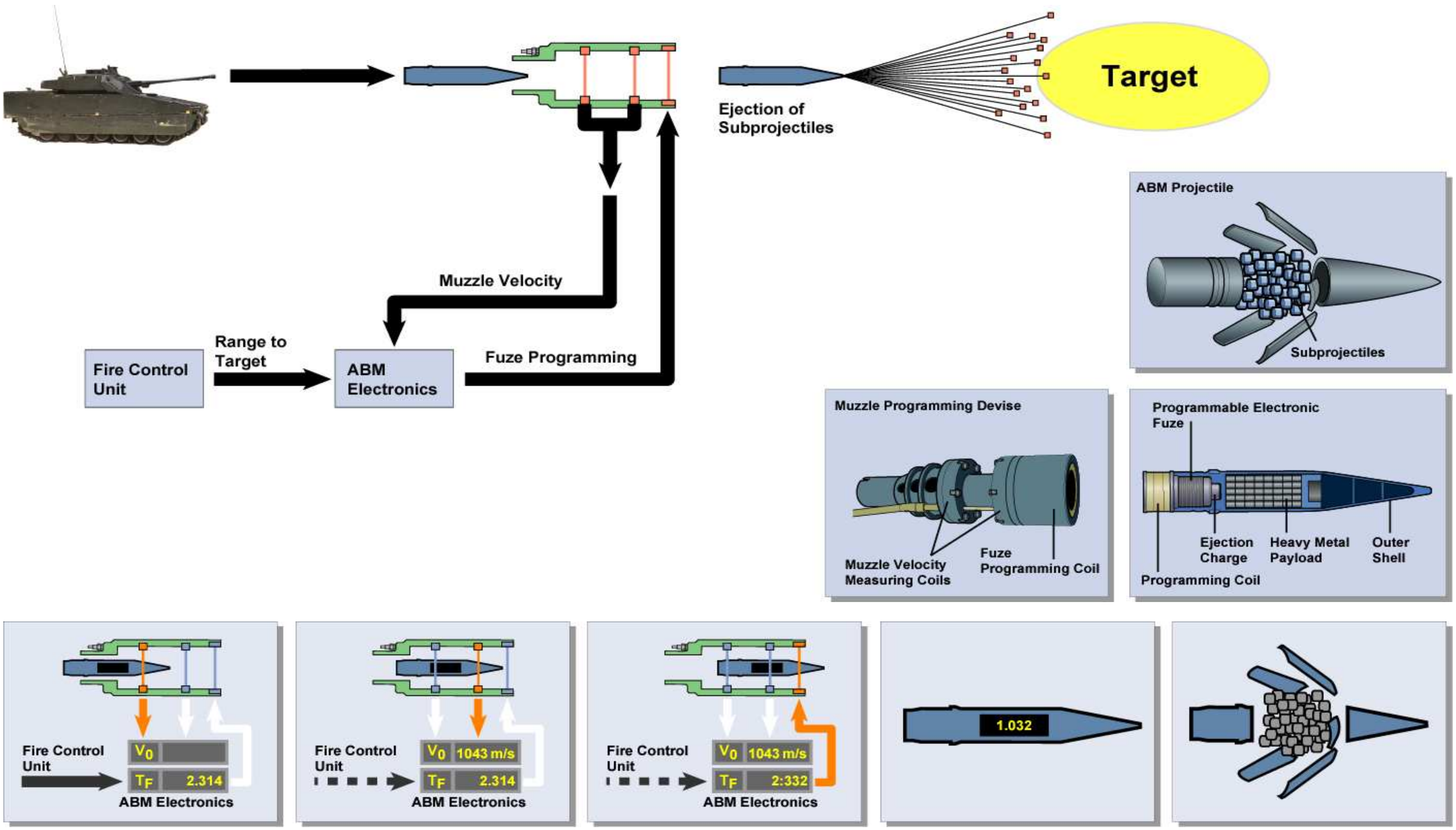
TNO | Knowledge for business

J.J.M. Paulissen
E. van Meerten (RWMS)
Th.L.A. Verhagen

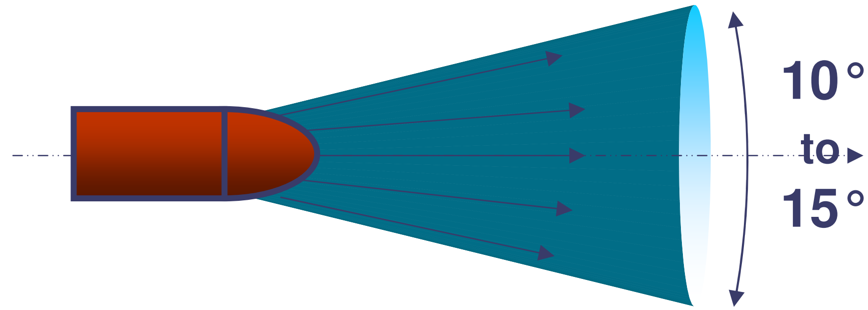
Contents

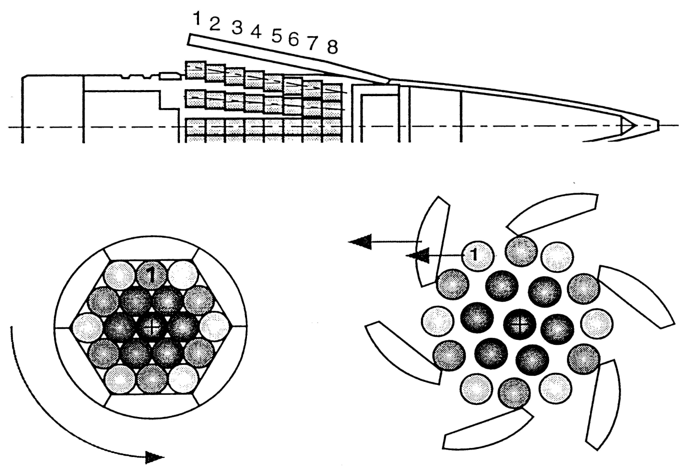
- ABM (KETF) modeling
- ABM (KETF) effects
- Firing doctrine for CV9035

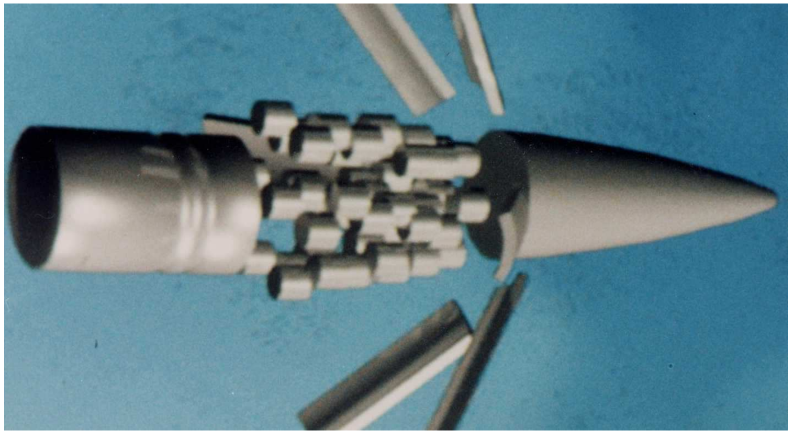
Functioning of KETF



Characteristics of ABM (KETF)

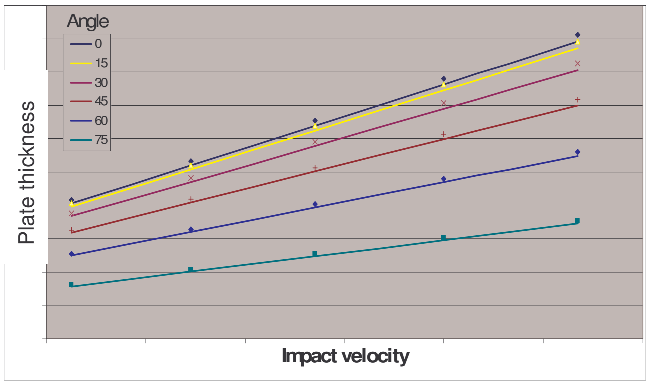


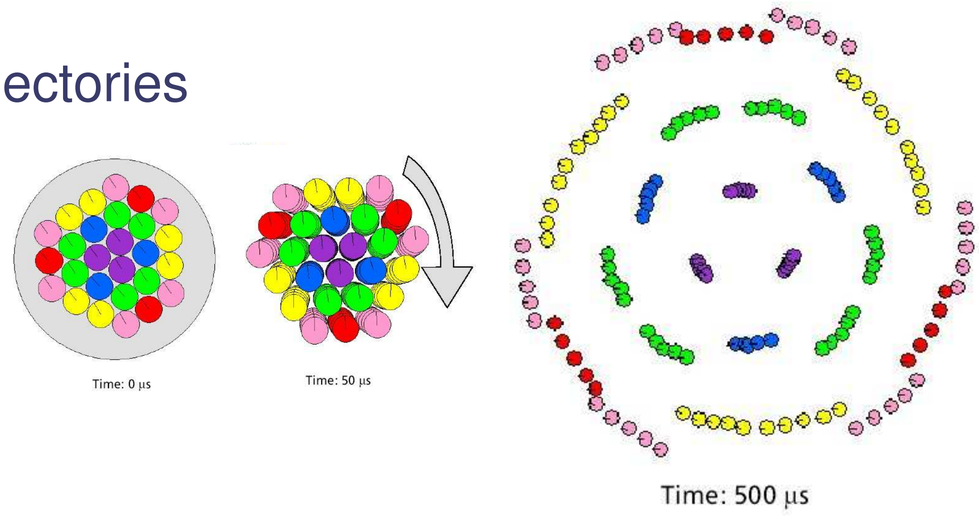




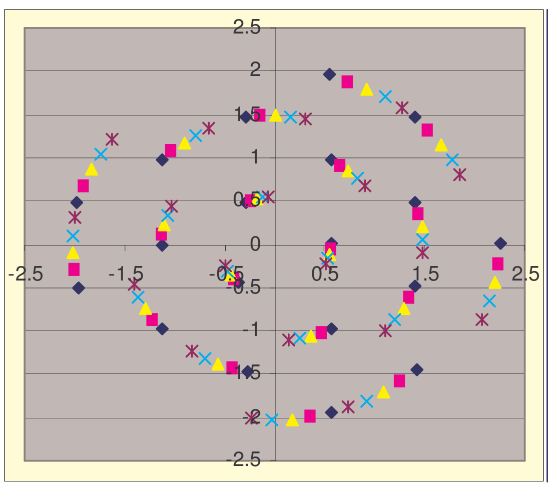
Modeling of ABM (KETF)

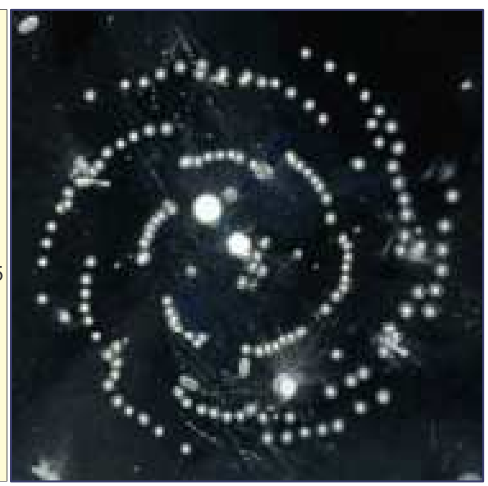
- Sub-projectile ejection and trajectories
- Sub-projectile penetration

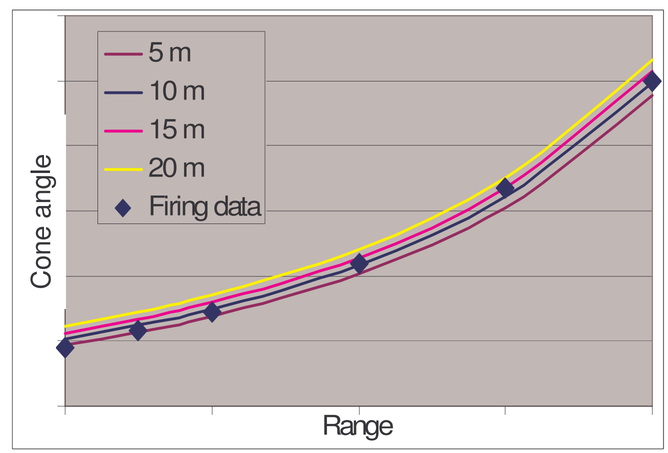




35 mm AHEAD







Effects of ABM (1/2)

- Burst of 3 rounds against F-104G Starfighter

Effects of ABM (2/2)

- Burst of 3 rounds against F-104G Starfighter

Input to TNO V/L modelling

Threat

Target

Interaction simulations

Target hit?
Target penetrated?
Components hit?
Damage to components?
Functioning of damaged components?
Functioning of damaged systems?
Readiness of damaged platform?

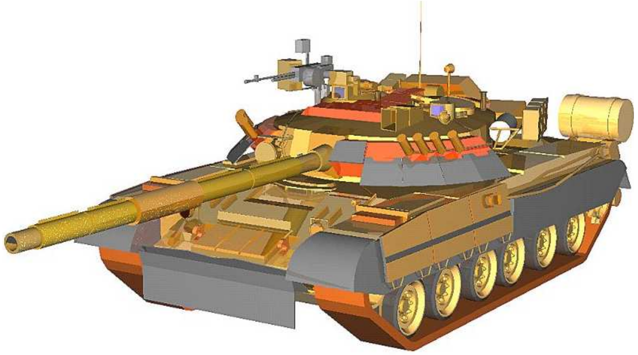
Lethality

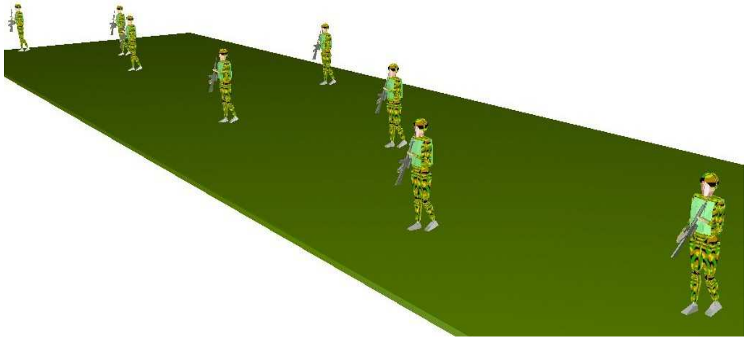
TARVAC

Vulnerability

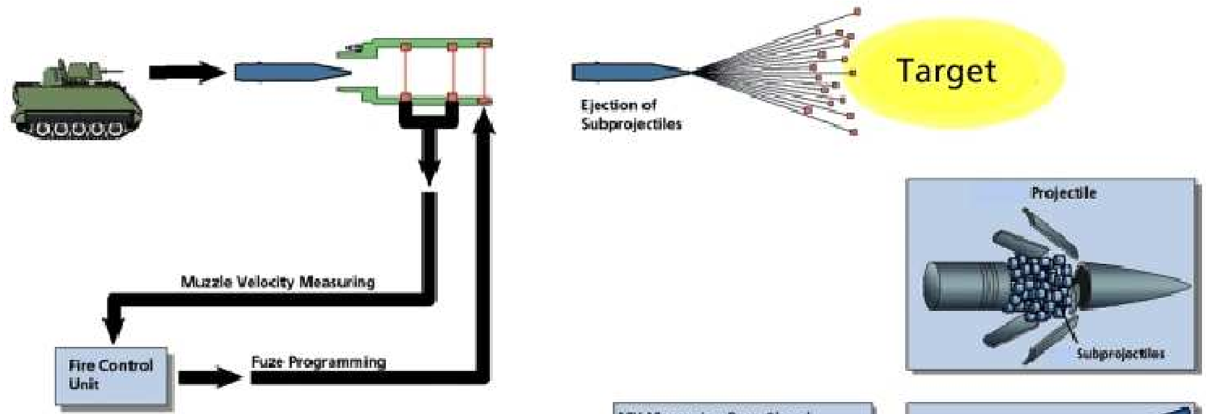
RNLA IFV Firepower

- Ammunition selection & modeling
- Caliber selection: 30 *or* 35 mm
- Ammunition optimization: firing trials with ABM sub-projectiles against optical sights, helmets, fragment resistance vests
- Firing doctrine development

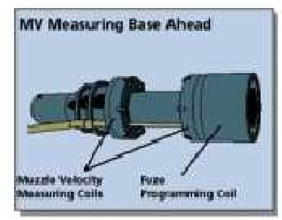




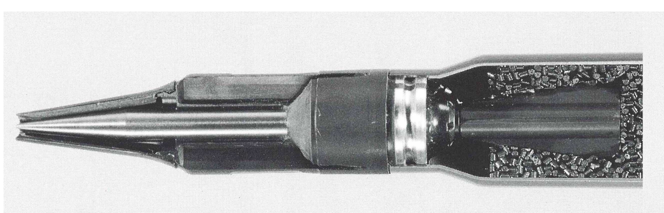
Ammunition selection

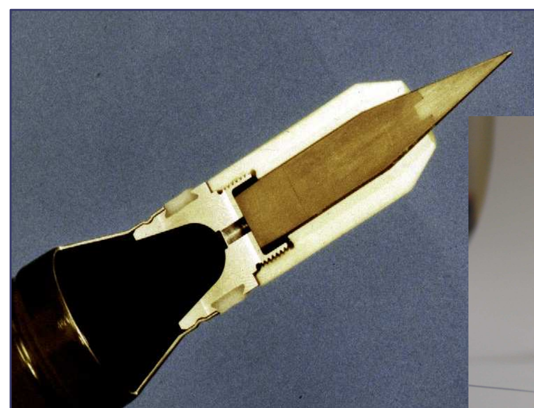


Air Burst Munition
HETF/KETF



APFSDS





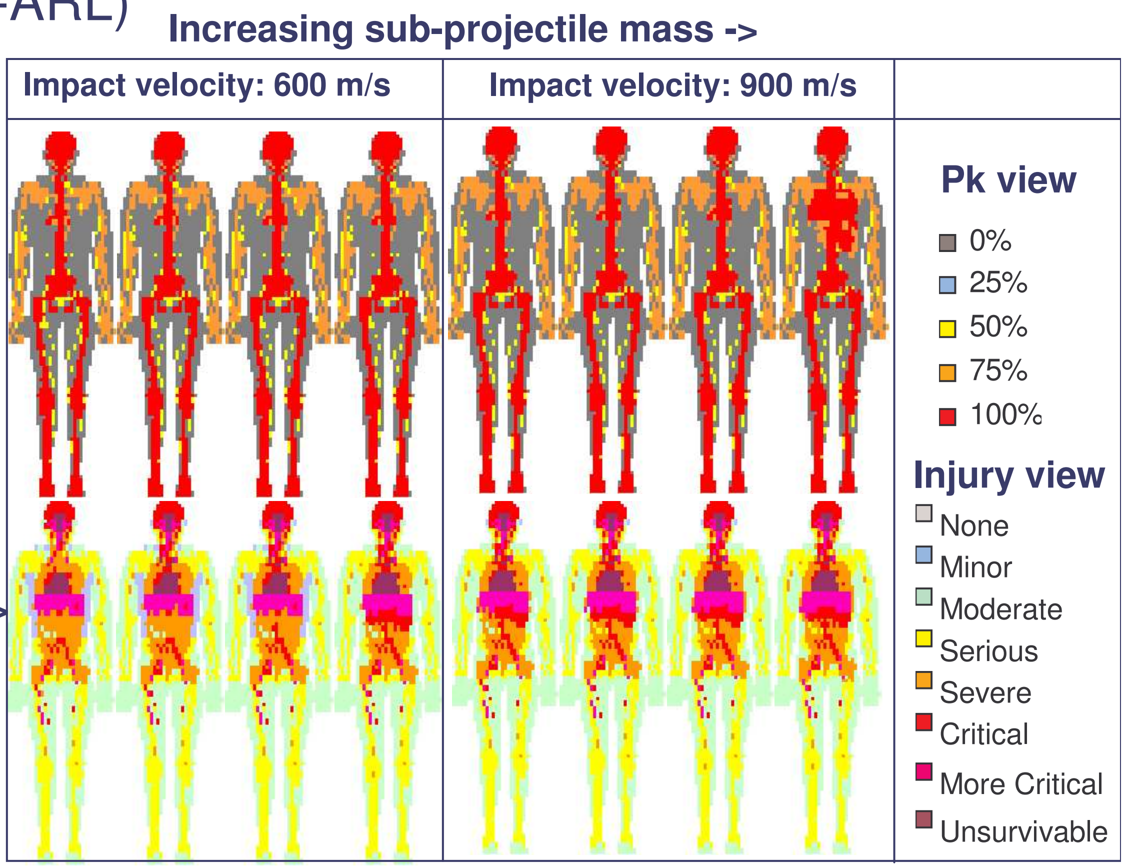
FAPDS/PELE

ABM (KETF) optimization

- Standing soldier, including helmet and vest, 30. sec assault
- Ballistic protection based on experimental data
- Using ComputerMan (US-ARL)

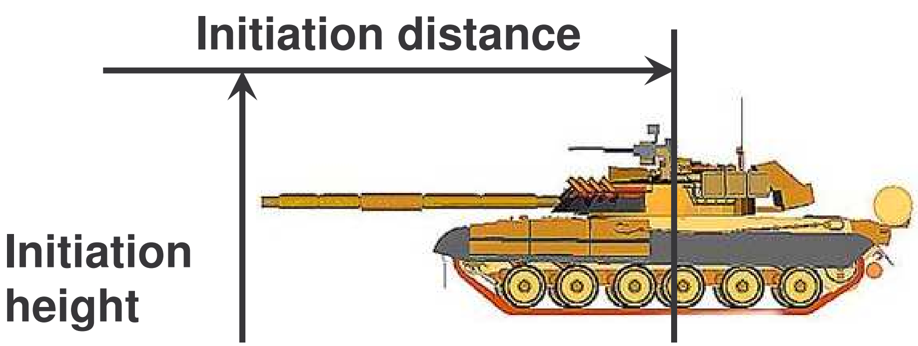
- Fixed total payload mass: heavier sub-projectiles results in smaller density of fragment cloud

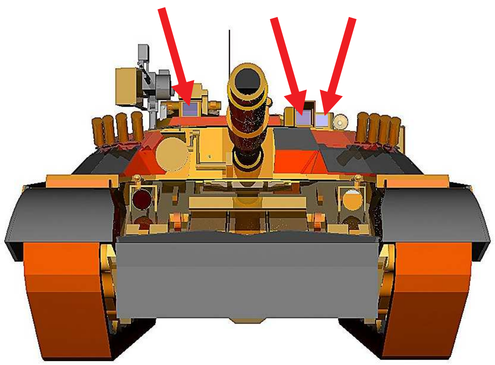
- Result: 35 mm KETF prototype is redesigned -> sub-projectile mass: 1.24 gram



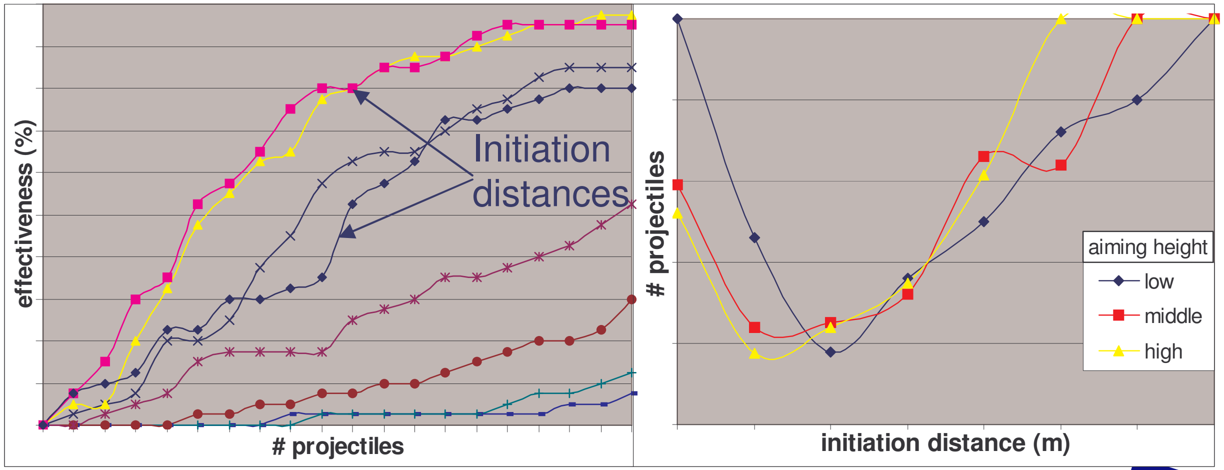
Firing doctrine (35 mm KETF against T-80U)

- Neutralise T-80U by killing all optical sights



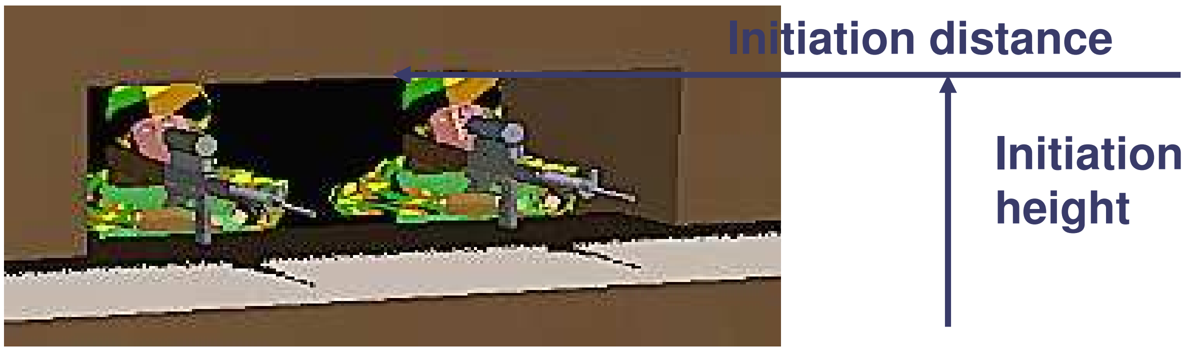


- Selection of initiation distance and height is essential for effectiveness KETF

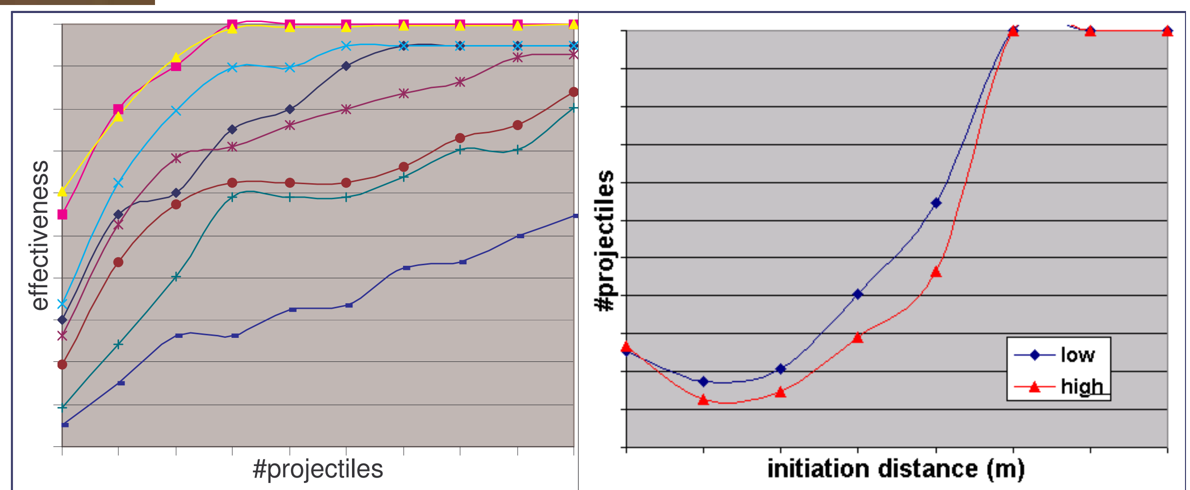


Firing doctrine (35 mm KETF against Foxhole)

- Kill two men covered Foxhole

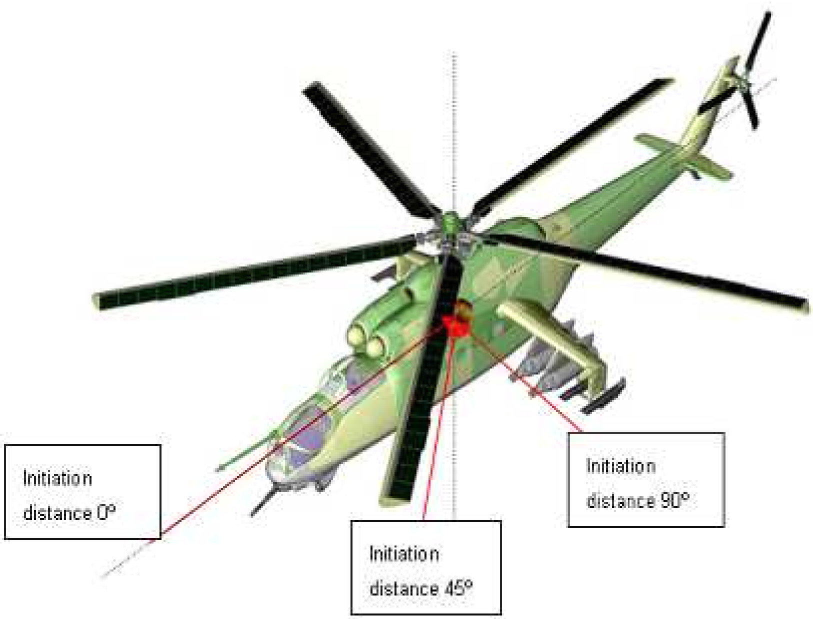


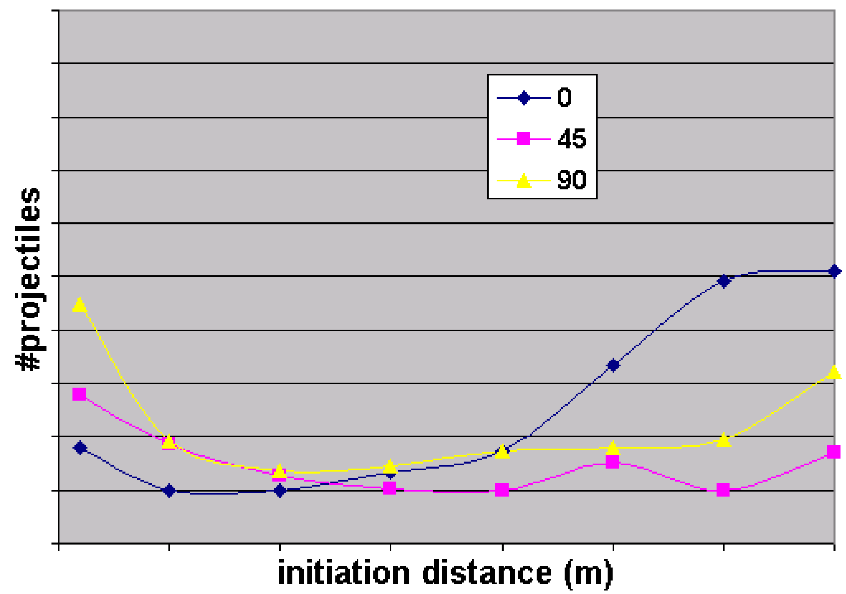
- Selection of initiation distance and height is essential for effectiveness KETF



Firing doctrine (35 mm KETF against Mi-24 Hind)

- Kill helicopter for three azimuth angles, 2000 m range
- K-kill, without manned control within 30 sec

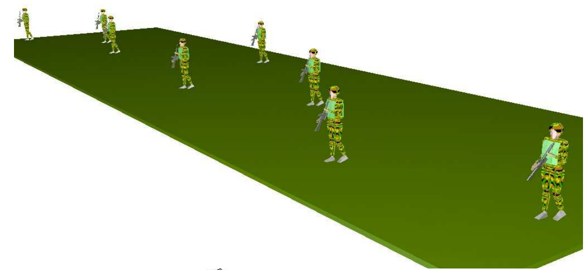




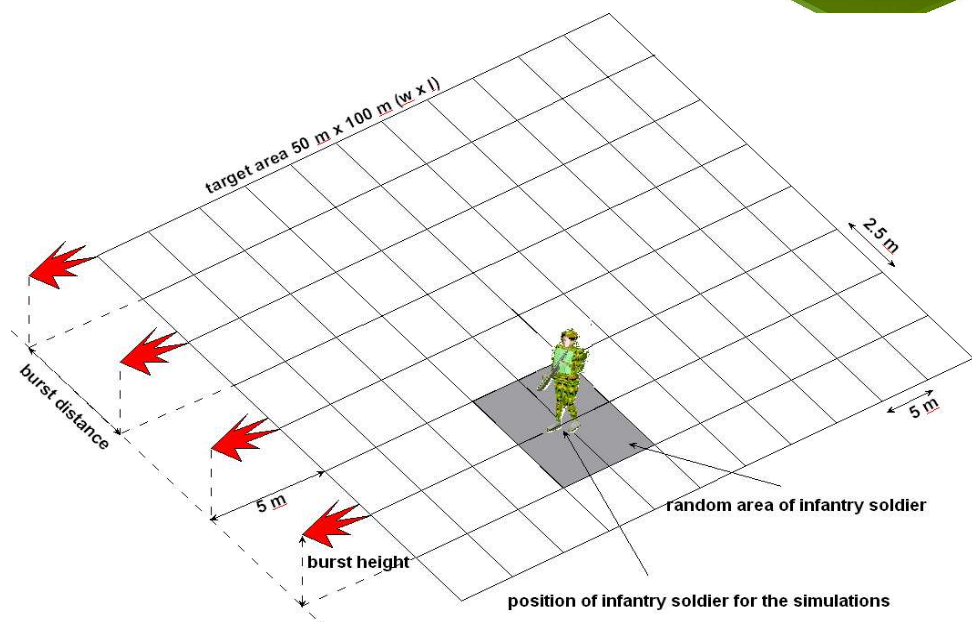
- For KETF the selection of initiation distance is essential for KETF effectiveness
- KETF is very effective against helicopter

Firing doctrine (dismounted soldiers in open field)

- Soldiers next to each other (line formation):
  8 men covering an area of 10 x 40 m
- Soldiers in column formation:
  5 men covering an area of 50 x 10 m

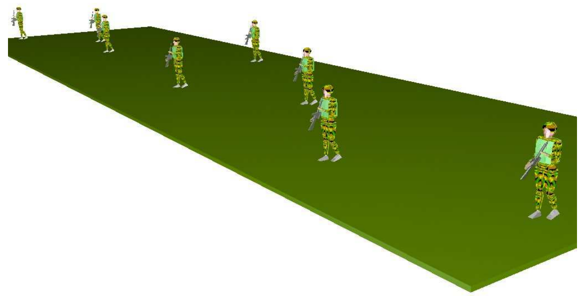


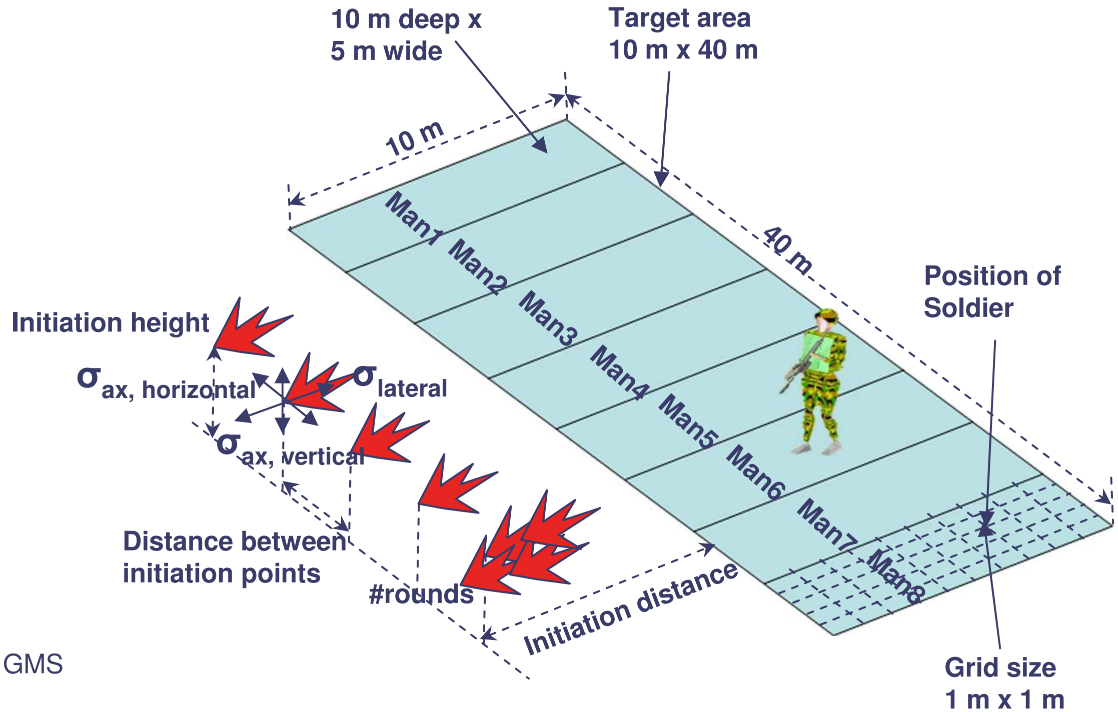
- Doctrine determined by combined variation of:
  - Initiation distance
  - Initiation height
  - Number of rounds
  - Distance between initiation points
  - System dispersions

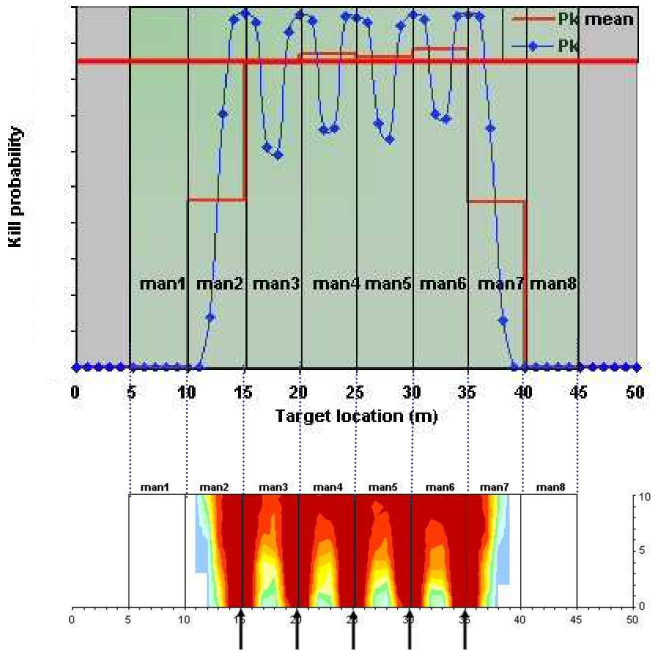


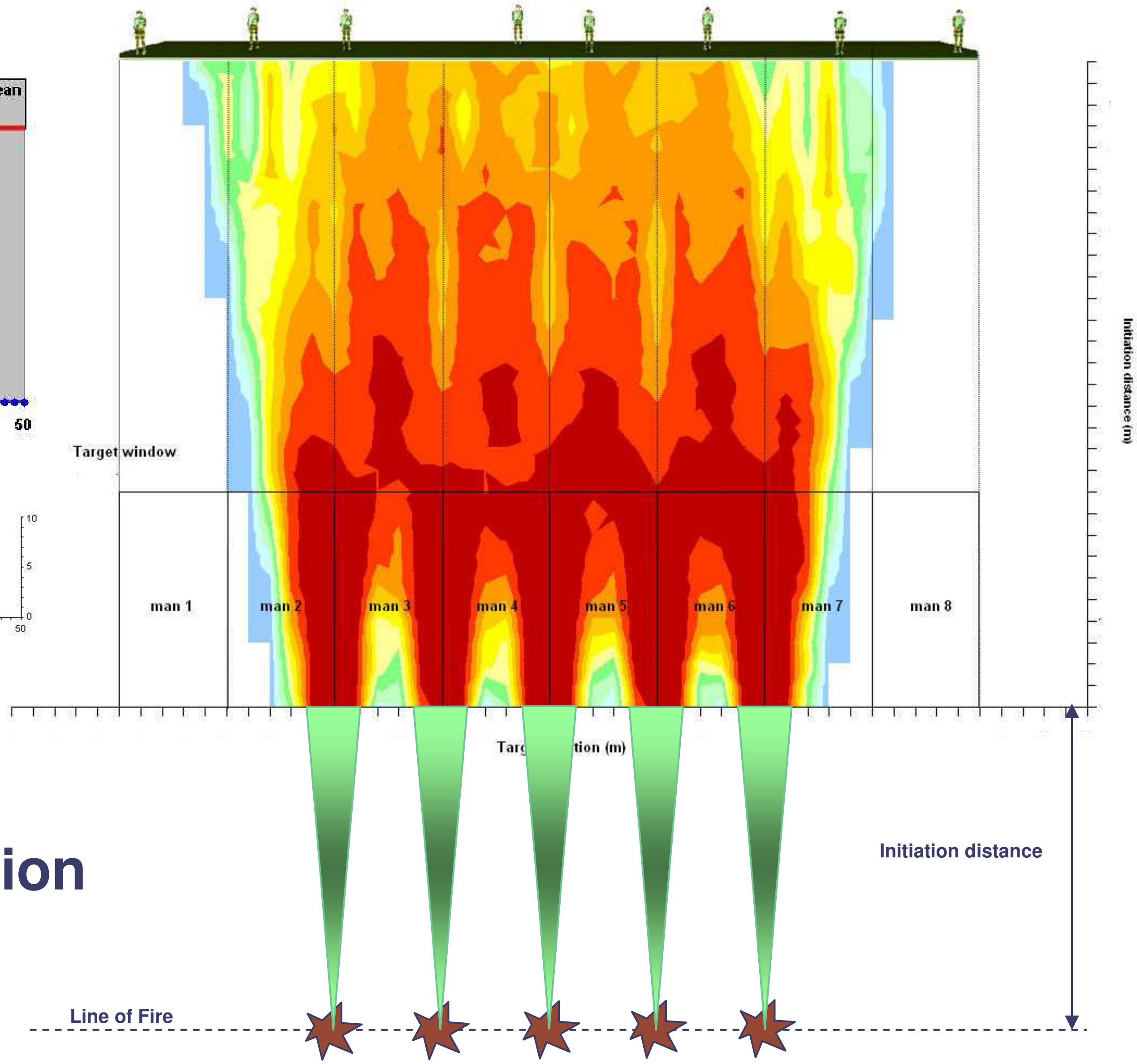
Firing doctrine (dismounted soldiers in open field)

- Initiation distance
- Initiation height (offset to aimpoint)
- Distance between initiation points
- Number of rounds in initiation point
- Total system dispersion is taken into account
- Tools: Fragment trajectory + ComputerMan



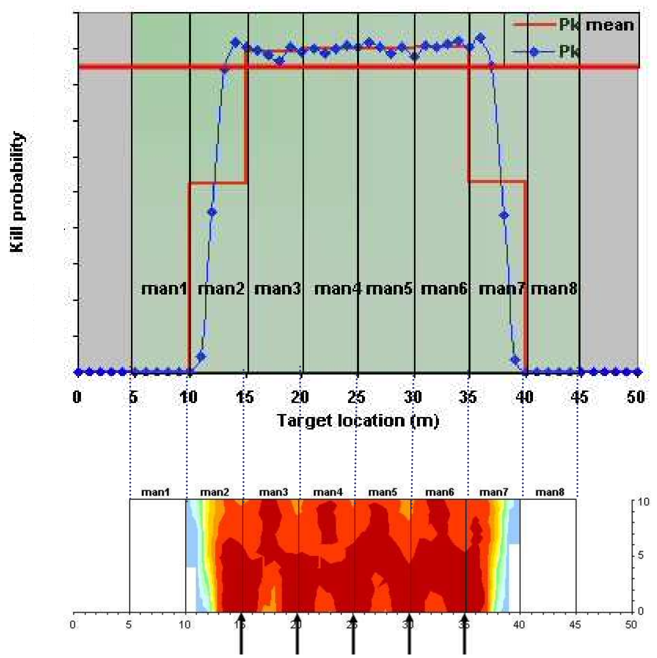


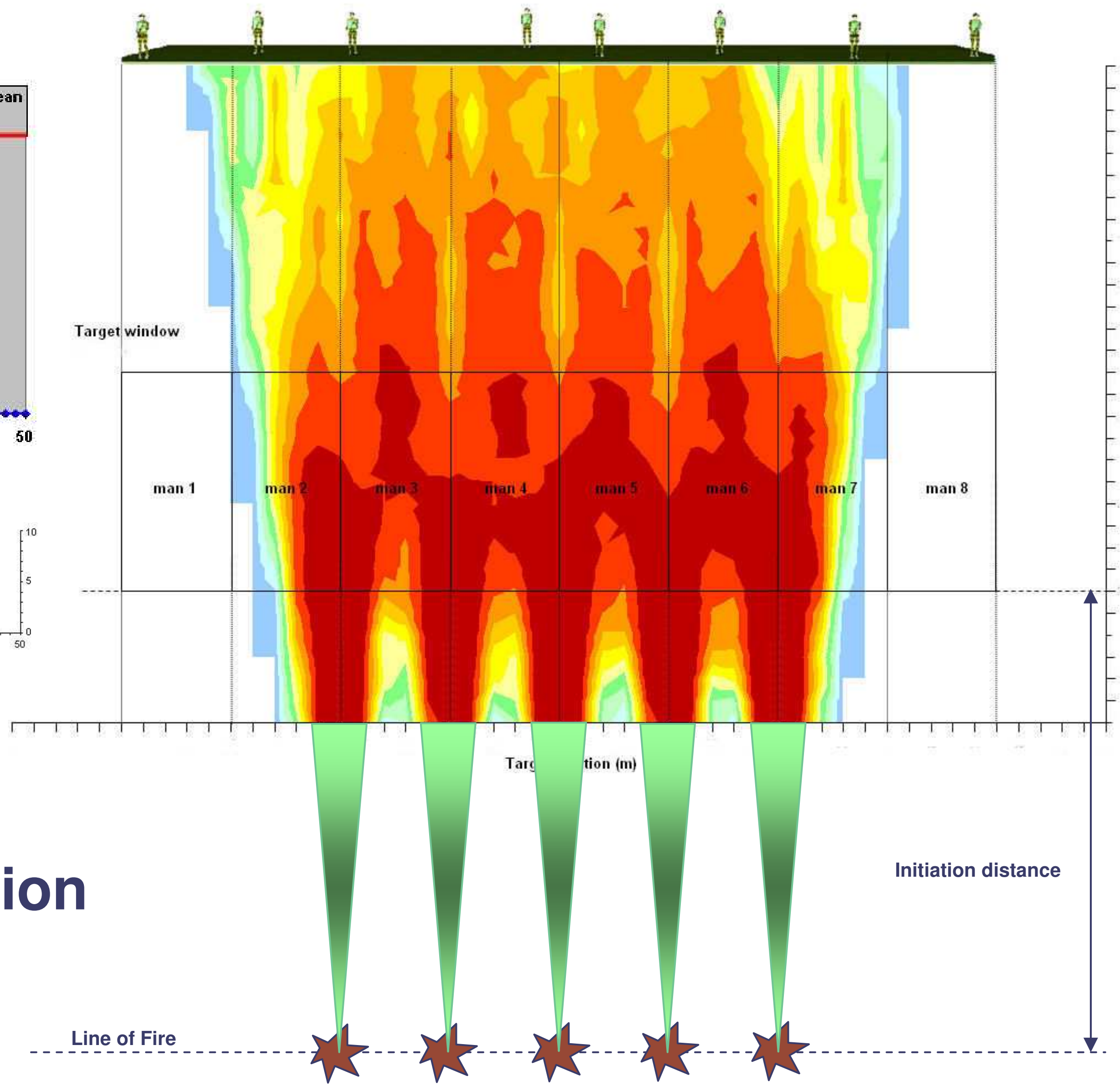




KETF initiation distance optimization

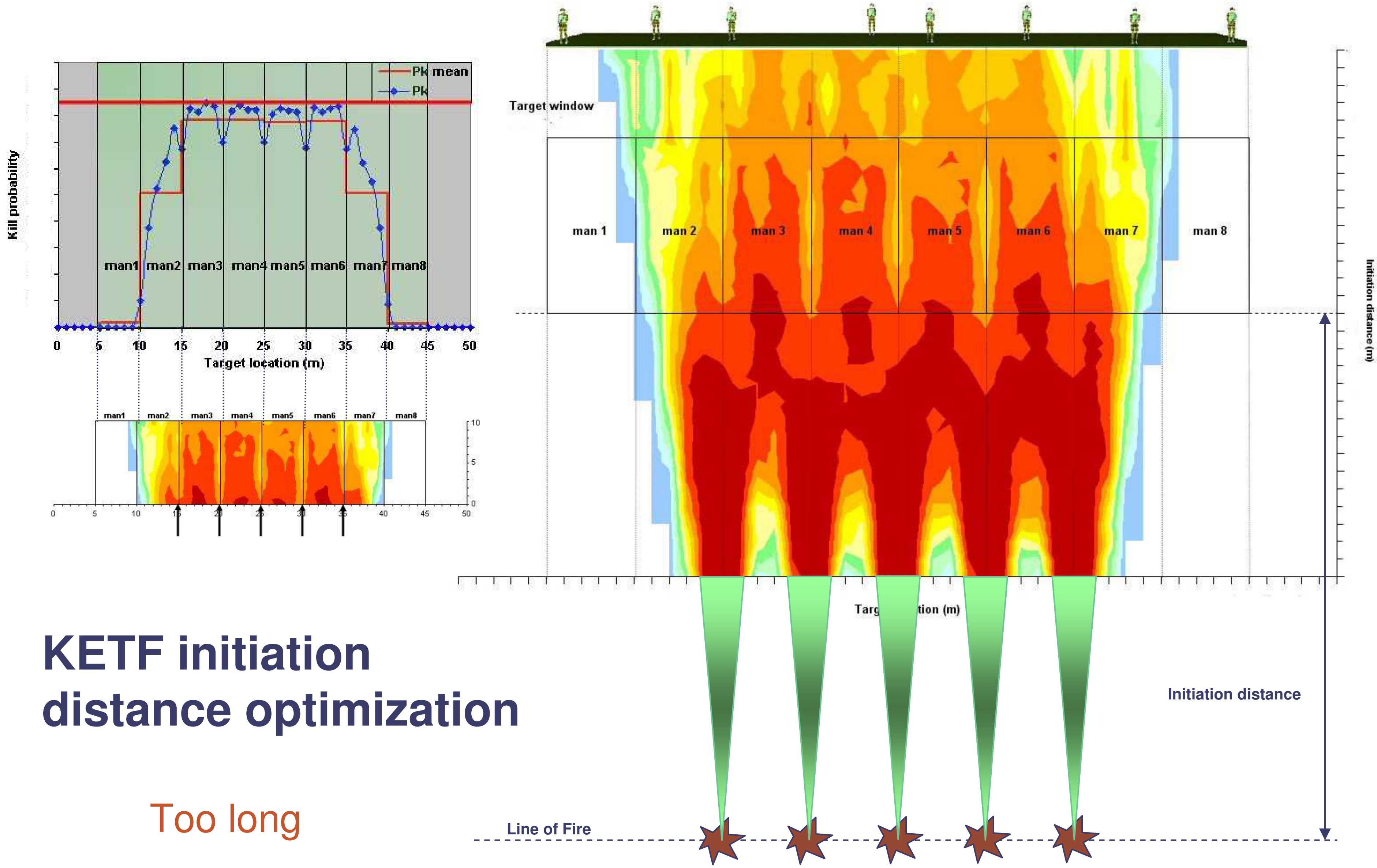
Too short





KETF initiation distance optimization

On target



KETF initiation distance optimization

Too long

CV9035 with 35 mm KETF

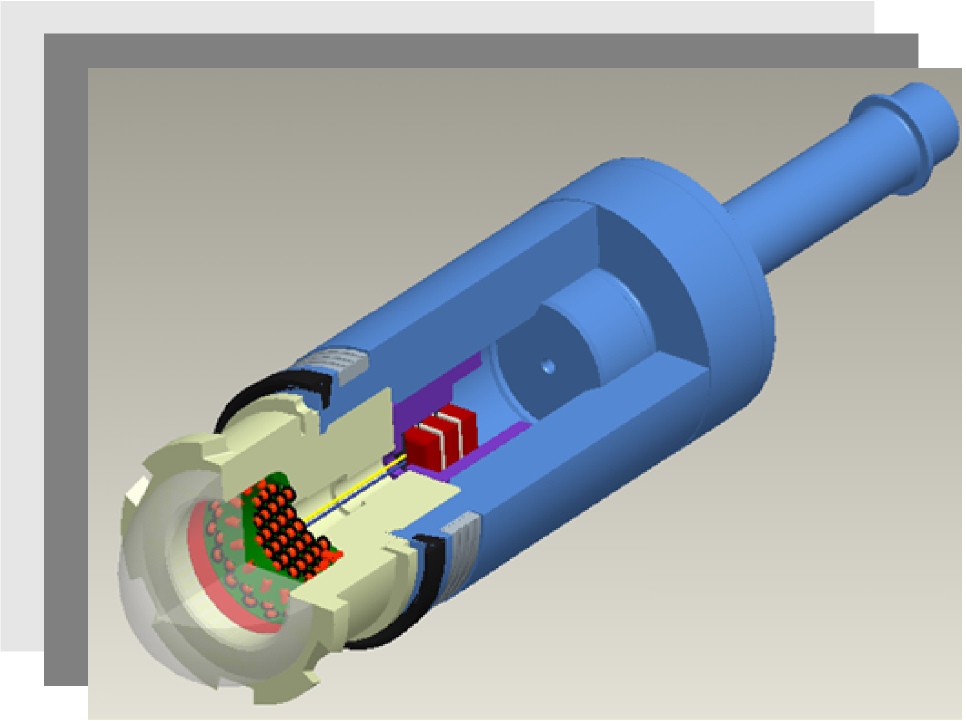
- The 35 mm KETF was selected for the RNLA IFV (CV9035) to fulfil the Firepower requirements
- Simulations proved essential in development of CV9035 Firing doctrine. Simulations based on an optimal balance between:
  - The number of fired projectiles
  - Initiation distance
  - Initiation height
  - Distance between initiation points
  - Time setting of the fuze

- Co-operation between operator, industry (RWMS) and TNO for projectile optimization
- Co-operation between operator and TNO for firing doctrine

TNO Weapon effectiveness simulation models

- **Medium caliber ammunition:**
  - Air Burst Munition:
    terminal ballistics & lethality models available
  - Frangible projectiles:
    terminal ballistics & lethality models available
  - PELE projectiles:
    terminal ballistics & lethality models under development

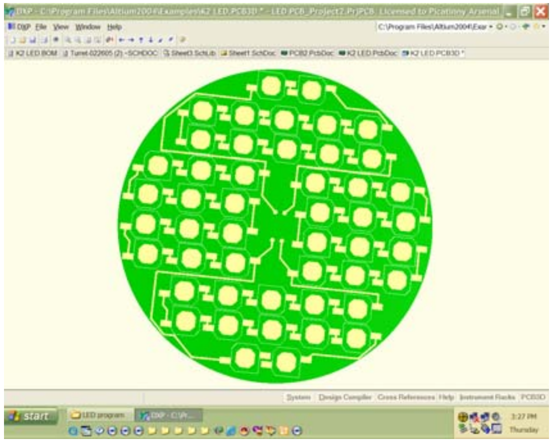
120mm Flameless Tracer

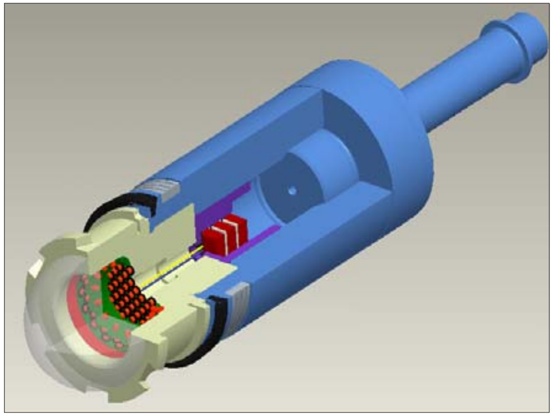


Presented by: John Kostka

7 April 2009

Flameless Tracer Design Description





Problem Statement: The current tank ammunition is prone to causing range fires that impede training exercises, research and development tests, and Lot Acceptance Tests (LAT's). Range fires add considerable delays during training and testing.

Proposed Solution: A non-pyro tracer made of Light Emitting Diodes (LEDs) will not cause range fires and reduces the amount of energetics in the round, improving IM characteristics.

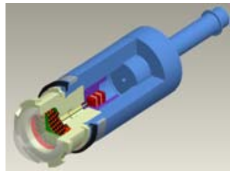
Description: The M831A1 and later the M1002 will be the test bed for this effort. An LED array will be place in the tailcone of the M831A1 with the power supply placed into the open cavity of the body.

Current Status

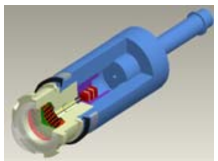
- 8 Design Configurations:
  - Red
  - Blue
  - White
  - Dark Blue
  - Yellow
  - Green
  - Variable Flash Rates
  - 2km, 2.5km, & 3km Distances
- LED Visibility at Requirement Distance (VRD) test
  completed Successfully
- LED Flameless Tracer in 40mm Grenade
  Component Survival and Function in 40mm Grenade completed Successfully
- LED Tracer Air Gun Test
  Component Survival and Function in High "G" Environment completed Successfully
- LED Tracer in 120mm M831A1 Ballistic Test planed.
  Currently working on Manufacturing hardware, electrical component testing and ballistic test scheduling.

Visibility at Required Distance (VRD) Test

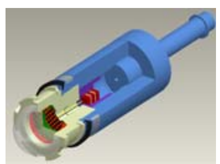
3 Km



2.5 Km



2 Km



- *Start at 2k, if successful, move to 3k, if unsuccessful, move to 2.5k.*

50 ft

- *Visible to tank optics and trained observers up to 50 ft left/right of tank*

<u>Variables</u>:

Distance

Color

Flash/Blink rate

<u>Information To Be Gathered</u>:

Brightness

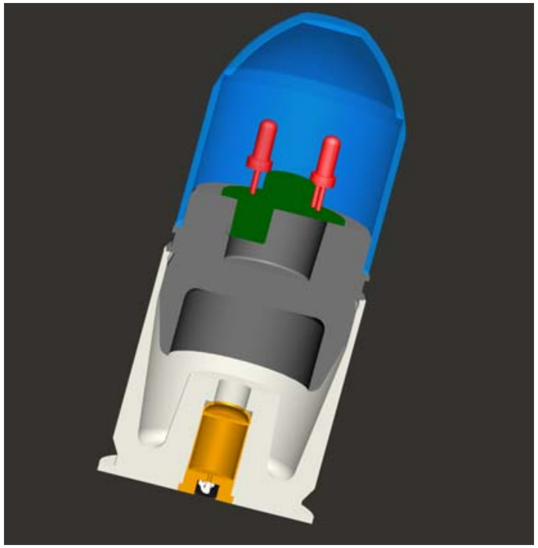
Intensity

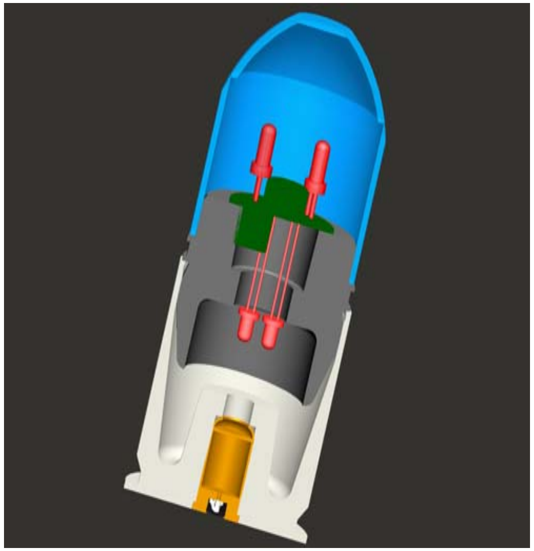
Comparison to current M831A1 tracer

<u>Success Criteria</u>:

LED tracer visible to binocular aided eye at tank location and to the left/right of tank.

Flameless Tracer in 40mm Grenade Test





Information Gathered:

- Visibility
- Survivability
- Recovered Projectiles

Success Criteria:

Design survives and is visible to target

LED Tracer Air Gun Test

Components Survival and Function in High "G" Environment

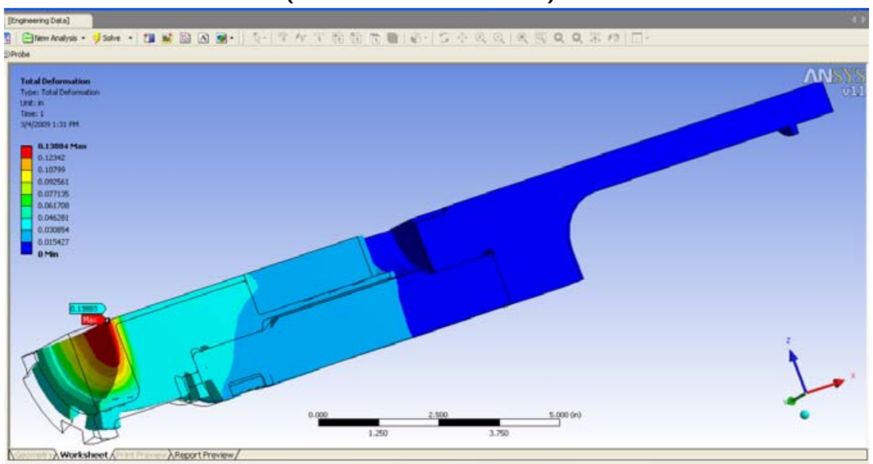
Oct-14, 16 -2008

- **Air gun test at Picatinny Arsenal.**
- **Plan three (3) tests: (25kG's, 35kG's, & 45kG's)**
- **Three LED arrays were tested.**
- **LED array and PCB board tested as a unit.**
- **LED function tested before and after each test.**
- **LED array, PCB board functioned perfectly after launch and recovery at G levels:**
  - **Shot 1: LED#1 24, 781G - Passed**
  - **Shot 2: LED#2 35,257G - Passed**
  - **Shot 3: LED#3 44,402G - Passed**

✓LED array, PCB board functioned perfectly after each launch and recovery!

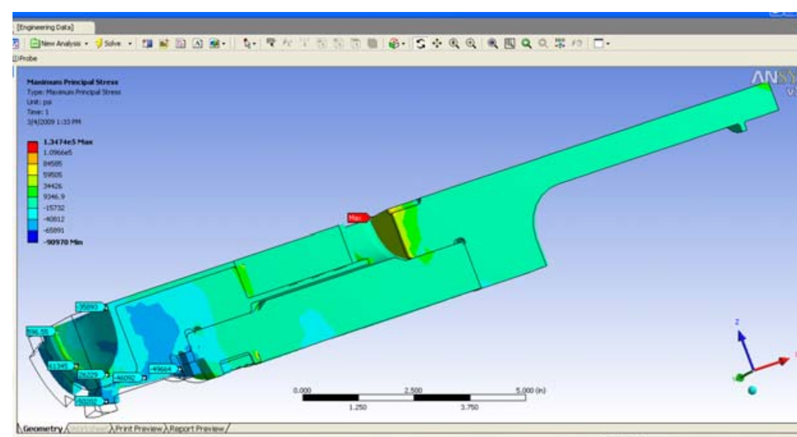
Flameless Tracer Ballistic Test I
Preparatory Work

Ansys Analysis
(Total Deformation)



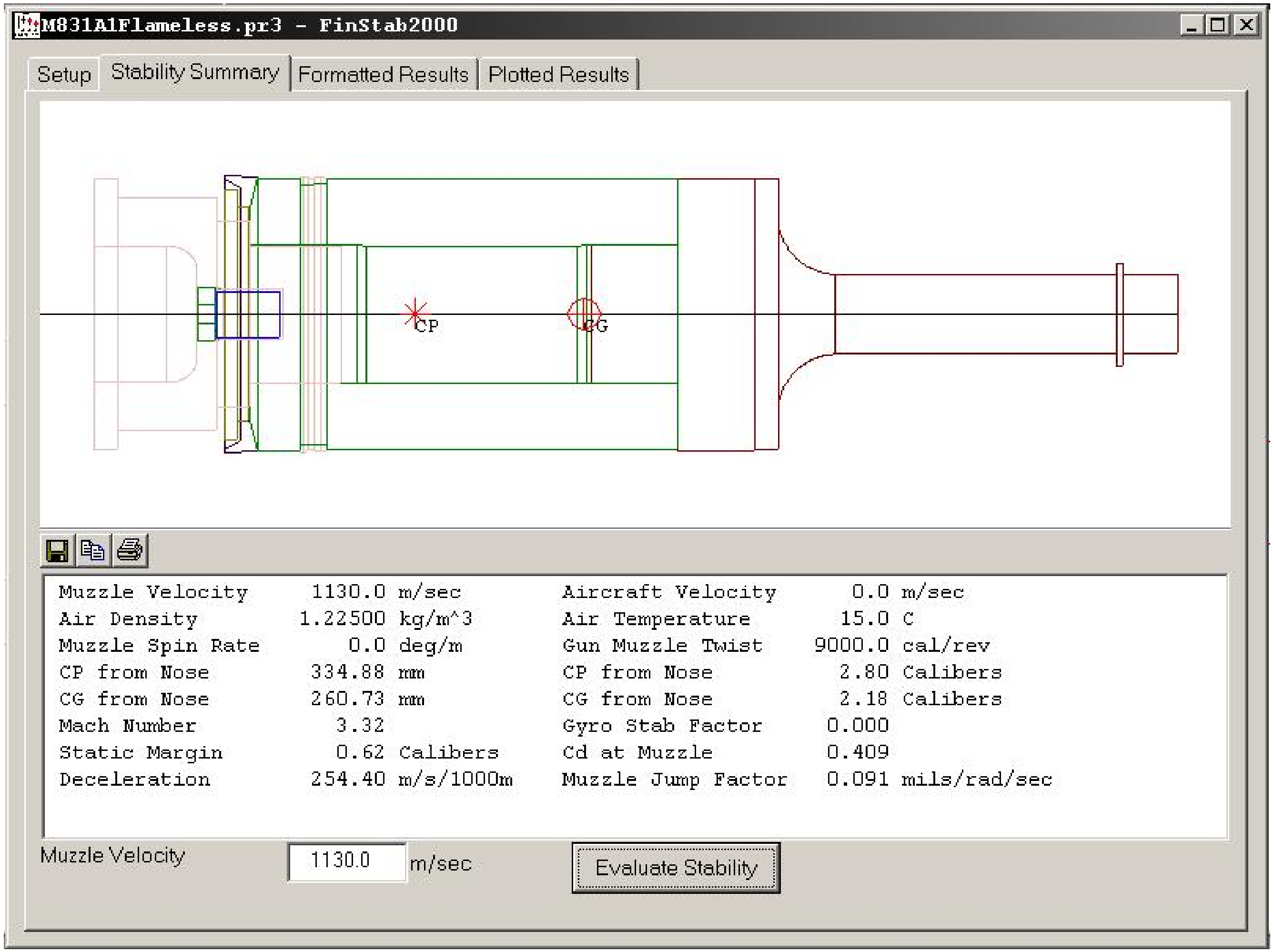
Analysis of the total deformation is less an 1/8” inch suggesting that the on board electronics should not be affected by gun launch.

Ansys Analysis
(Maximum Principal Stress)



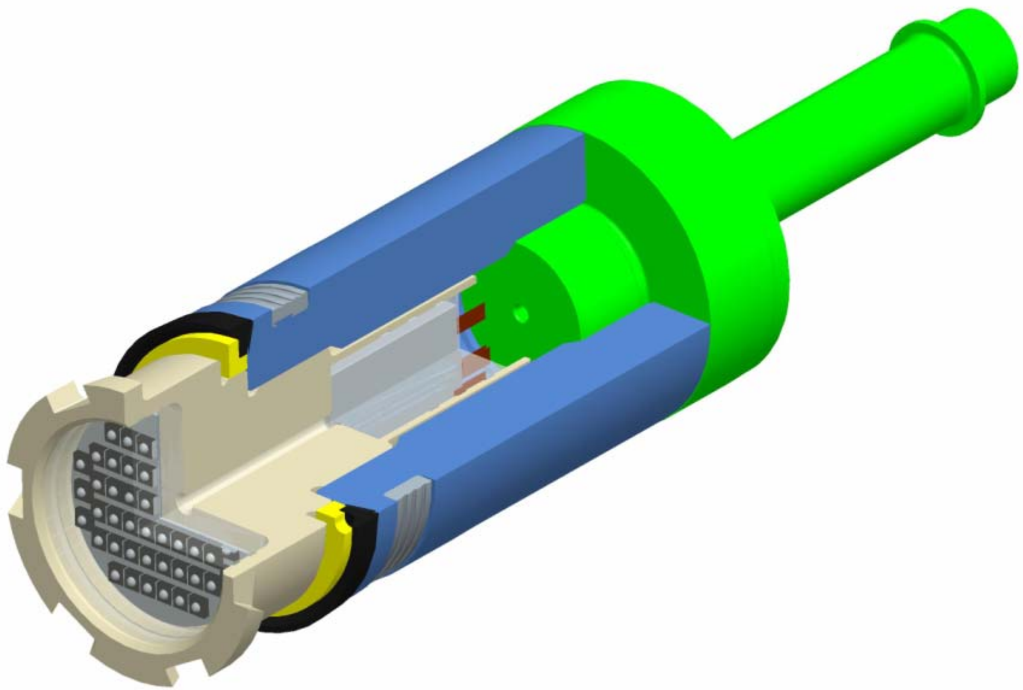
Analysis of maximum principal stress indicates that the modified projectile should survive gun launch.

Prodas Analysis



Stable within with range 1143 m/s - 600 m/s MV

Flameless Tracer Ballistic Test I



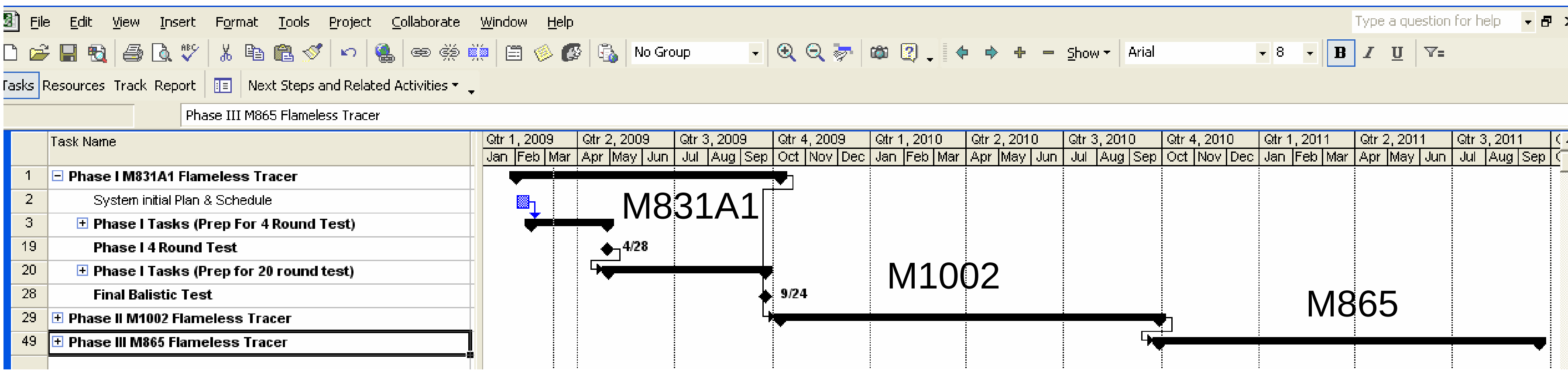
<u>Information to Gather</u>:

Video tracking to 2km
Hadland photos at 7m & 15m
Visibility naked eye & binocular
Survivability
Recovered Projectiles
and other typical LAT data.

<u>Success Criteria</u>:

The design survives setback
and is visible to target
Exterior ballistics are unaffected
The test is completed
without incident

Program Schedule



- Proof of concept designing and testing - complete
- Phase 1a testing in the M831A1 schedule for May 2009
- Phase 1b strength of design testing scheduled Oct 2009
- Phase 2 M1002 flameless tracer completion Oct 2010
- Phase 3 M865 flameless tracer completion Sept 2011

Future Possibilities

- Link Flameless Tracer To M1002 Nose Switch:
  - Use different color for Ground vs. Air setting
- Use Flameless Tracer To Simulate Air Burst M1002
  - Use different blink pattern to simulate Air Burst
- Replace Batteries With Capacitors
  - Charge Capacitors through data link

Issues/Concerns

- M1002's 3km visibility range requirement is the longest of any training round.

  Resolution: Enough power will be included for the ~4 seconds of flight. Brighter LEDs are expected on the market this year.

- The M1A2 series tank's CITV is a thermal optic which may not pick up the LEDs in flight.

  Resolution: An IR emitting LED can be added to the array, or the CITV might pick up the forward edge heating of the projectile in flight.

- It will be a challenge to fit the LED array and battery/capacitor into the M865's fin configuration.

  Resolution: The current tracer cup and fin design may be modified to accommodate the LEDs. Less power will be required for the M865's shorter flight time to target. Future efforts will shrink the size of components.

- Current tank training round tracer costs $10-$12.

  Resolution: Future efforts will be required to reduce the cost of any design created by this effort.

RDECOM

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

Advanced Celluloid Technology for 120mm Mortar Propelling Charges

Brian Talley, Elbert Caravaca, Howard Shimm, Kimberly Chung, Pete Bonnett, Joe Palk (ARDEC)
Ming Wan Young, Linjie Zhu, Costas Gogas (PPI)

NDIA Conference
44th Annual Gun & Missile System Conference
Kansas City, April 7, 2009

Status Report

Objective

- Develop a material to replace the current felted fiber used on all mortar propelling charges.
  - Increase durability and decrease cost.

Technical Requirements

- Establish production footprint and manufacture small lots of containers
- Optimize material to meet system requirements

Benefit

- Cost savings
- No reduction in ballistic performance
- Increased strength and durability based on rough handling testing.

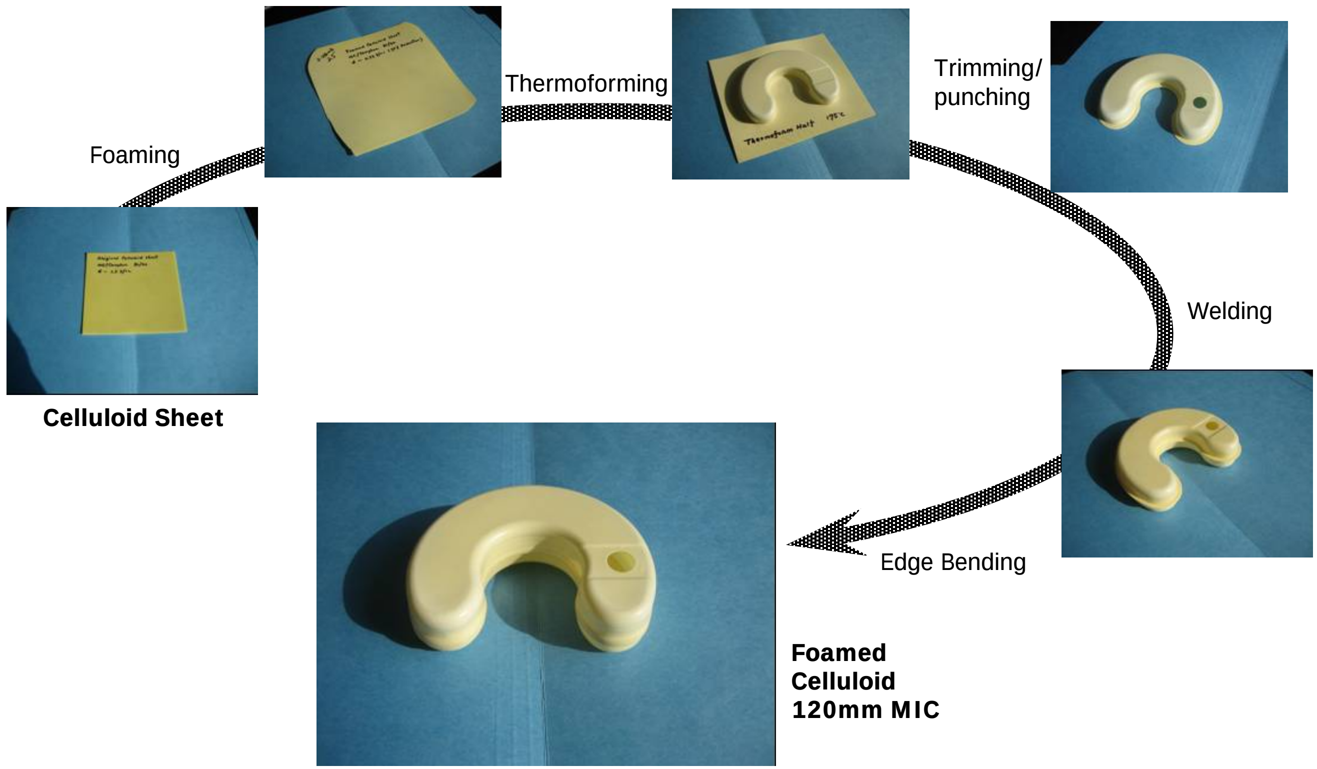
Outstanding Issues or Concerns:

- Celluloid manufacture not yet established in the US

Background

- Currently use **felted fiber** for 60, 81 and 120mm mortar propelling charges.
  - No definitive way to test for leaks or ensure that the container halves are bonded.
- **Celluloid- NC + Camphor**
  - Potential to reduce cost by 50% and eliminate the need for a solvent to bond the two halves of the mortar increment container.
  - Opportunity to implement automated inspection systems.
  - Successful Tests
    - Hot/Dry Cycle
    - Bare Immersion Testing
  - Marginal Test Results
    - Residue
    - Brittle in cold weather conditions
- Currently investigating **Advanced (Foamed) Celluloid**
  - NC + Other Additive Chemicals
  - Larger surface area and more porous than celluloid
    - Increased burn rate and enhanced ability to withstand impact
  - Successful tests
    - Residue, Extreme Temperature Performance, Bare Immersion, Secured and Loose Cargo

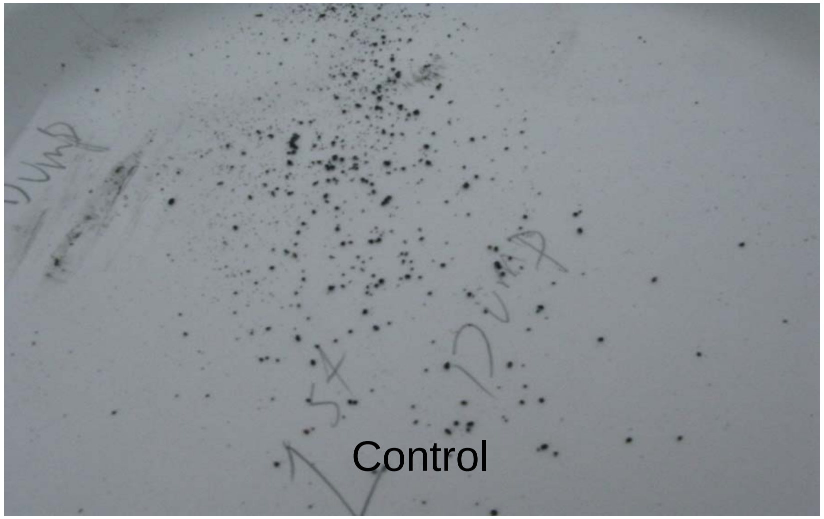
Foamed Celluloid Process

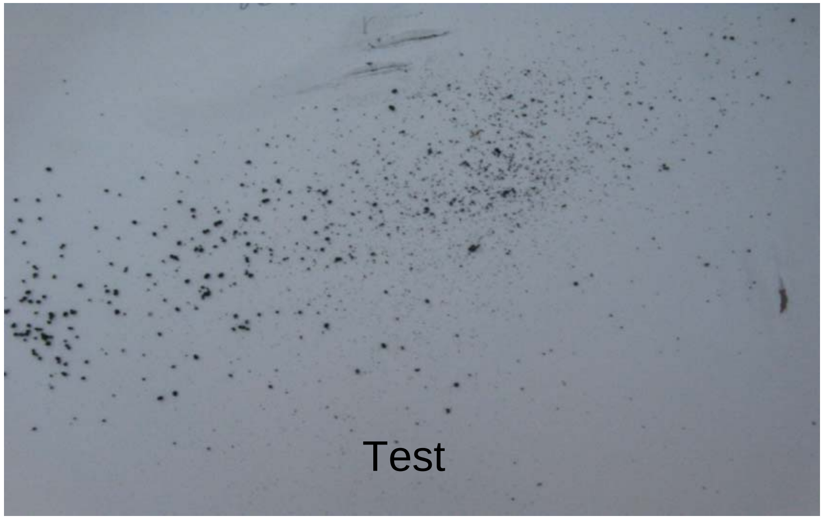


Residue Testing

- Tested 10 control rounds (felted fiber) and 20 test rounds (foamed celluloid) at 70 deg F
  - Results
    - No burning embers
    - Minimal to no residue
    - Results were similar to control rounds (felted fiber)
    - Test was successful

Residue Test Pictures

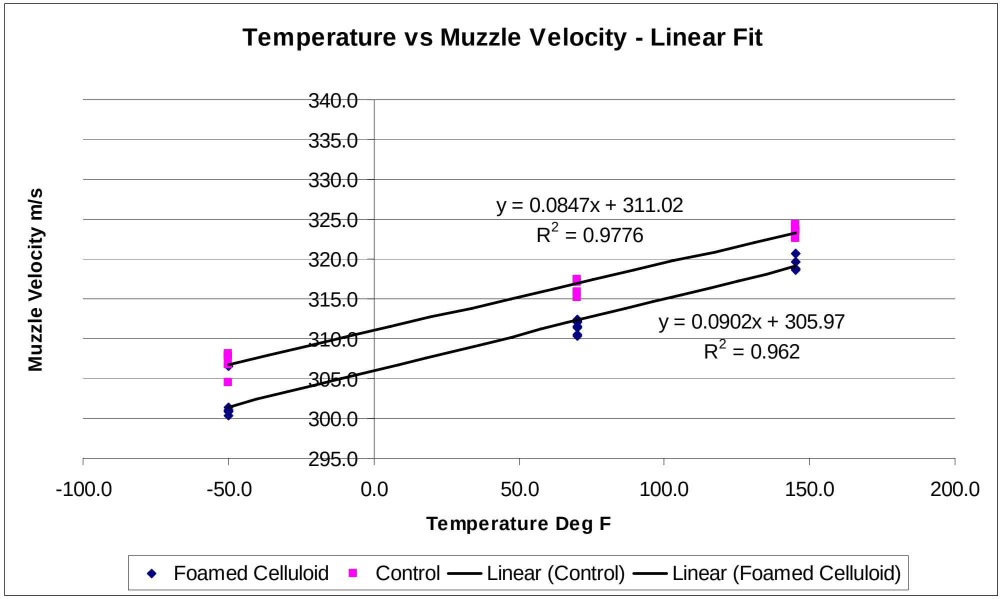

Control


Test


Control (Tarp)

Test (Tarp)

Extreme Temperature Performance



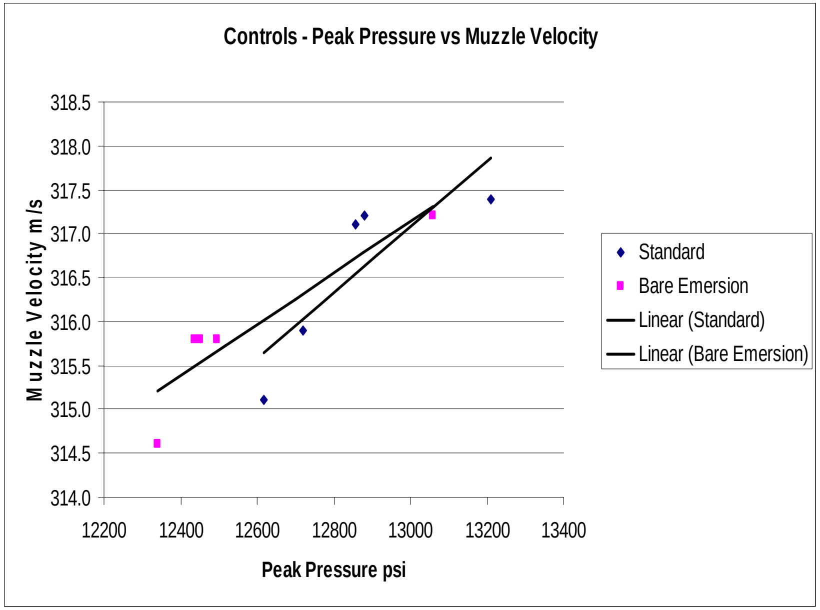
- Tested 5 controls and 7 test (foamed celluloid) at each temperature (-50 F, 70 F and 145 F)
  - The foamed celluloid cases exhibited the same shift in velocity and peak pressure as the felted fiber cases.
    - Verifies no change in performance at extreme temperatures
    - Miscalculation of charge weight results in non-overlapping of the two data sets.

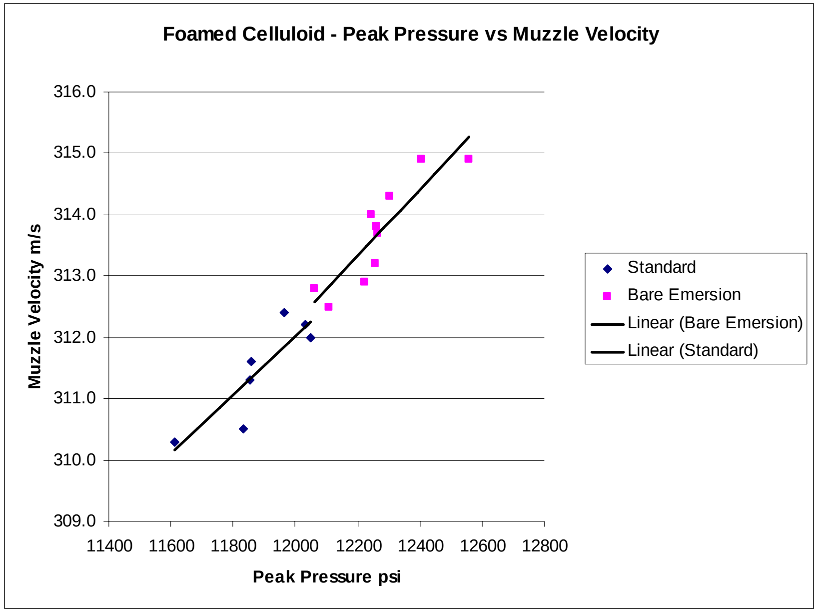
Bare Immersion Test

- Tested 5 controls and 10 test rounds (foamed celluloid) at 70ºF
  - Results
    - Propelling charges were submerged under 8 cm of water for 10 seconds then immediately fired
    - Adjustment of the charge weight can correct the velocity and pressure differences.
    - Test was successful

	Control	Test	Control	Test
	Peak Pressure (psi)		Muzzle Velocity (m/s)	
Normal	Standard	-7.55%	Standard	-1.58%
Bare Immersion	Standard	-2.28%	Standard	-0.66 %

Bare Immersion Test continued





- Foamed Celluloid resulted in better data groups and had a more consistent effect on performance

- Control rounds resulted in an overlap and wider spread of the results

Secured Cargo

Test

Control

Secured Cargo			
	Hot 145 F		
	Test	Control	
Total Tested	24	12	increments
Total Damaged	6	5	increments
Defects Observed	Damage at seams (ID) and face	Damage on near seams (ID) and face	
	Cold - 60 F		
	Test	Control	
Total Tested	24	12	increments
Total Damaged	1	2	increments
Defects Observed	Damage at one end of propelling charge	Damage at one end of propelling charges	

Loose Cargo Results

Test

Control

Loose Cargo			
	Hot - 145 F		
	Test	Control	
Total Tested	48	24	increments
Total Damaged	4	2	increments
Defects Observed	Damage at seams (ID)	Damage at seams (ID)	
	Cold - 60 F		
	Test	Control	
Total Tested	48	24	increments
Total Damaged	1	0	increments
Defects Observed	Damage at seams (ID)	Damage at seams (ID)	

Potential Applications for Foamed Celluloid

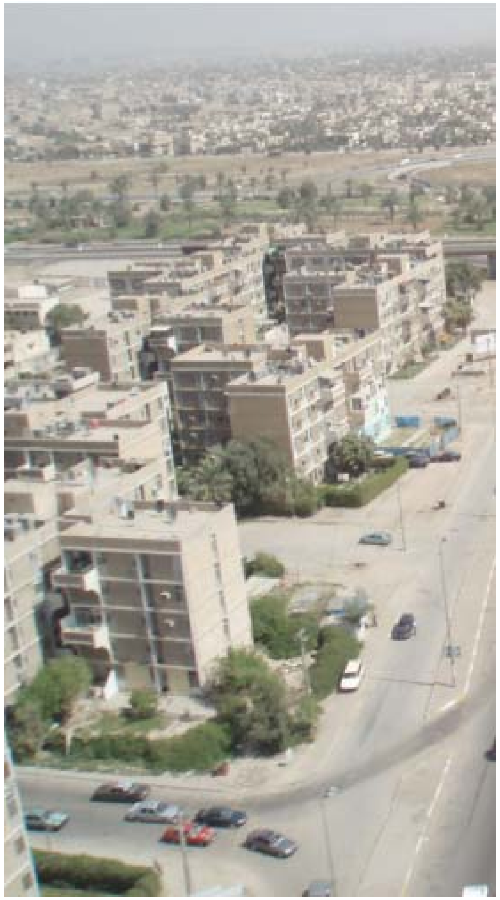
- Existing combustible case materials
- 40mm burst disc replacement
- 81mm Illumination expulsion cup
- Ignition cartridge parts
    - Mortar ignition cartridge paper tube assembly replacement
    - Flashtube
    - Tank and Artillery
- Propellant coating
- High Hat Increments (M234 Redesign)

Precision Urban Mortar Attack (PUMA)

Bryan Freeman
NSWCDD G31
540-653-4156
540-413-6732 (mobile)
Bryan.Freeman@navy.mil

Operational Overview

- Precise, Low Collateral Damage Weapons for Combat in Urban Terrain:



  - Enable attacks on the enemy currently masked from indirect fires.
  - Overcome limits imposed by Global Positioning System (GPS) multi-path and signal masking.
  - Reduce risk of collateral damage.
  - Provide an organic attack capability.
  - Provide precision attack; mortars are inherently inaccurate.

Urban Scenario

MPLD System Major Design Specs

UAS LST
- Detect and track Class 1M Designator
- Fit in Tier 2 Payload

- Future Manned Aircraft LST
  - Modify existing LITENING pod
  - Permit LST of both MPLD and traditional designation

UAS Designator
- MPLD designation from Tier 2 altitudes
- Covert
- Fit in Tier 2 Payload

Future Manned Aircraft Designator
- Permit both MPLD and traditional designation

3000 ft AGL

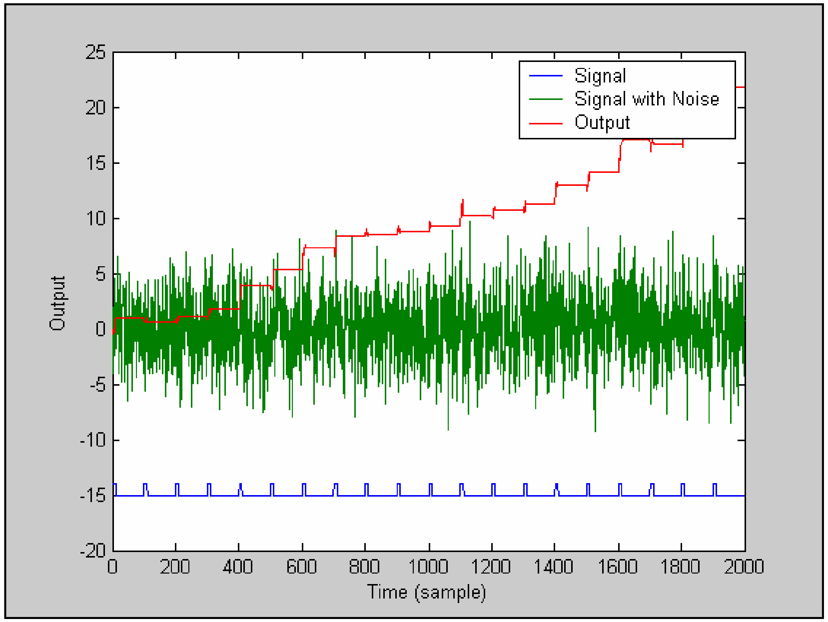
Ground Designator
- <5 lbs Total System Weight
- Eyesafe (unaided eye)
- Match designator engagement ranges
- Covert

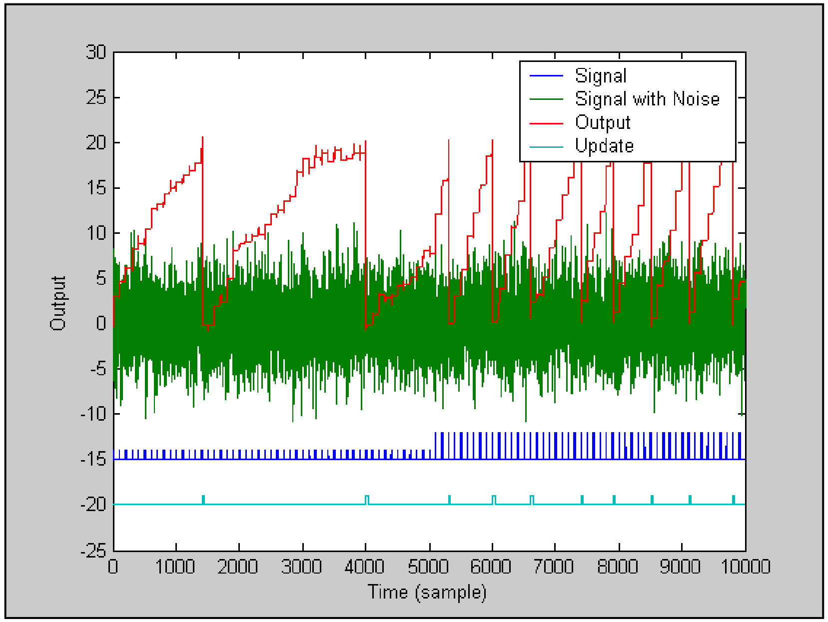
Weapon Seeker
- Work with GPS guided 81mm/120mm mortars, 155mm artillery shells
- Stand alone (GPS denied) desired

MPLD Core Technology

- MPLD is very different from current laser designator/marker technologies
  - Traditional designators
    - 50-120mJ+ per pulse, 10-20 Hz pulse rate, instantaneous power in MW range
    - Single pulse detectable
    - Class 4 non-eyesafe
  - MPLD Designation
    - 1-5uJ per pulse, 3-20 KHz pulse rate, instantaneous power in hundreds of watts
    - Requires many pulses to detect (covert)
    - Class 1M unaided eye safe

MPLD Core Technology





Like GPS, integration of the signal+noise using the proper code (PRF) allows us to pull the signal out of the noise.

With a constant signal to noise, the data rate will increase as we close on the target. This is needed to reduce miss distance and <u>occurs naturally!</u>

MPLD Ground Designator

- Design Goals
  - **Lightweight!**
    - Must be much lighter than current 28 lb PLDR designator
    - Integration into existing and near-future rangefinders a major plus
    - Integration into UAS targeting ball for UAS based designation
  - Eye Safety
    - Class 1M sufficient for MPLD and PUMA goals
    - May need to increase to provide marking under all weather for fast movers
  - Covert
    - Inability to see spot or designator source without knowing proper laser code

MPLD Laser Spot Tracker

- Design Goals
  - UAS
    - Must fit within targeting ball
    - Must have sufficient detection range to lock onto spot at a range of 1.5 Km
  - Manned Aircraft (Not part of MPLD or PUMA)
    - Desire that the existing LITENING G4 be capable of seeing ground MPLD designator spot

BRITE STAR II

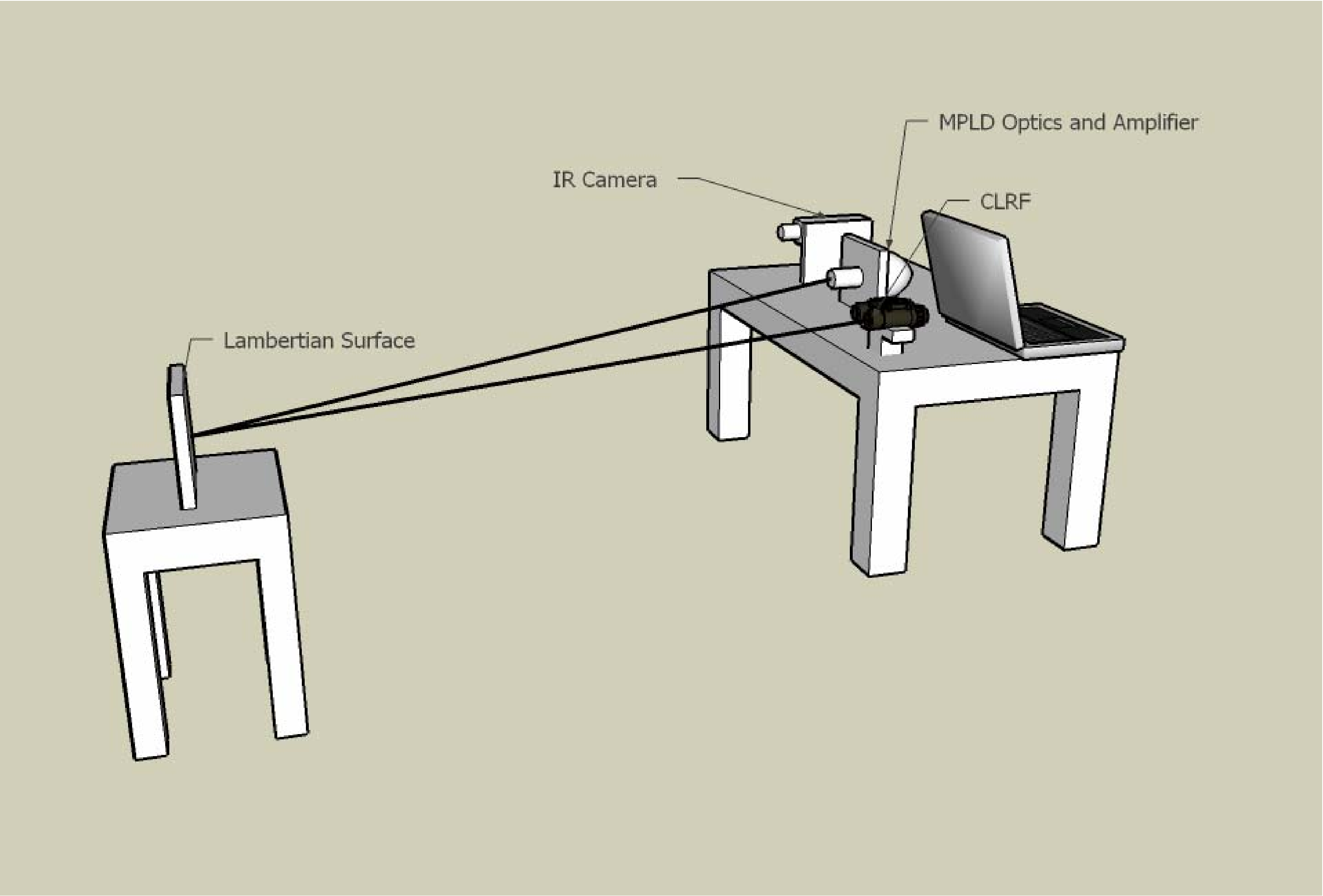
LITENING G4 POD

MPLD Weapon Seeker

- Design Goals
  - Mortars/Artillery
    - Must have sufficient FOV and processing power to handle body dynamic motion
    - Must fit within small space claim
    - Must be inexpensive (AUR < $5000)
  - Air Delivered Weapons
    - "Dual Mode" traditional designation and MPLD designation highly desirable

FCMortar/SMortar 81mm Conceptual Drawing

Designator/Seeker Prototype Test Setup



Micro Pulse Laser Designation (MPLD) System

Technical Status

- FY09
  - 1540nm prototype completed and demonstrated
    - Preamp issues solved
    - Optical issues solved
    - Real-time lock-on and track (two channels)
    - Approaches modeled prediction of performance
  - Analysis of 1540nm vs. 1064nm in process
    - 1064nm wavelength looks more promising at this time, final decision April 2009

Technical Status

- FY09
  - Weapon guidance requirements studied
    - Pulse processing model developed
    - Detection and guidance performance range determined
    - Preliminary FOV requirements determined
  - Working to complete 1064nm seeker design (will reuse all 1540nm processing and algorithms)
  - UAS LST requirements and algorithm development to begin

Technical Plans

- FY10
  - UAS Targeting/Designation System Selection
    - Vendor selection via BAA launched early FY10
    - Down-select completed and Contract preparation by end of FY10
    - Contract Award early FY11
  - UAS LST Prototype
    - Breadboard proof-of-concept system
    - Demonstration of system on a range
    - Delivery of system design to UAS Targeting Designation System vendor
  - HWIL Seeker FCMortar (81mm)
    - Integration with FCMortar hardware
    - HWIL testing and demonstration

MPLD/PUMA Solicitations

- Key Solicitations
  - FY09/10 S&T
    - Seeker producibility study for laser guided munitions
    - MPLD integration into existing laser range finder
    - BAA: N00178-08-Q-1904 on NSWCDD web site
  - FY10 Announcement (Pending)
    - EO/IR/LST integration into a Tier 2 UAS targeting ball
    - Solicitation FY10, award at beginning of FY11

Questions?

Technology Innovations Realized in the M150/M151 Dismounted Fire Control System Development

Authored By

Amit Makhijani

&

Ralph Tillinghast

Overview and Outline

Overview

The purpose of this paper is to present the technological innovations achieved in the development of the M150/M151Dismounted Mortar Fire Control System, Winner of the 2007 Dod Top 5 Program Award.

- Outline
  - Acknowledgments
  - M95/M96 Overview
  - M150/M151 Overview
  - Innovation Highlights
    - Replacement of Legacy Computer
    - Power Distribution / Communication Upgrade
    - Driver and Gunners Display
    - PDMA
    - System Cables
    - Configuration (modular E-Rack)
  - Conclusions
  - Video & Questions

Acknowledgments

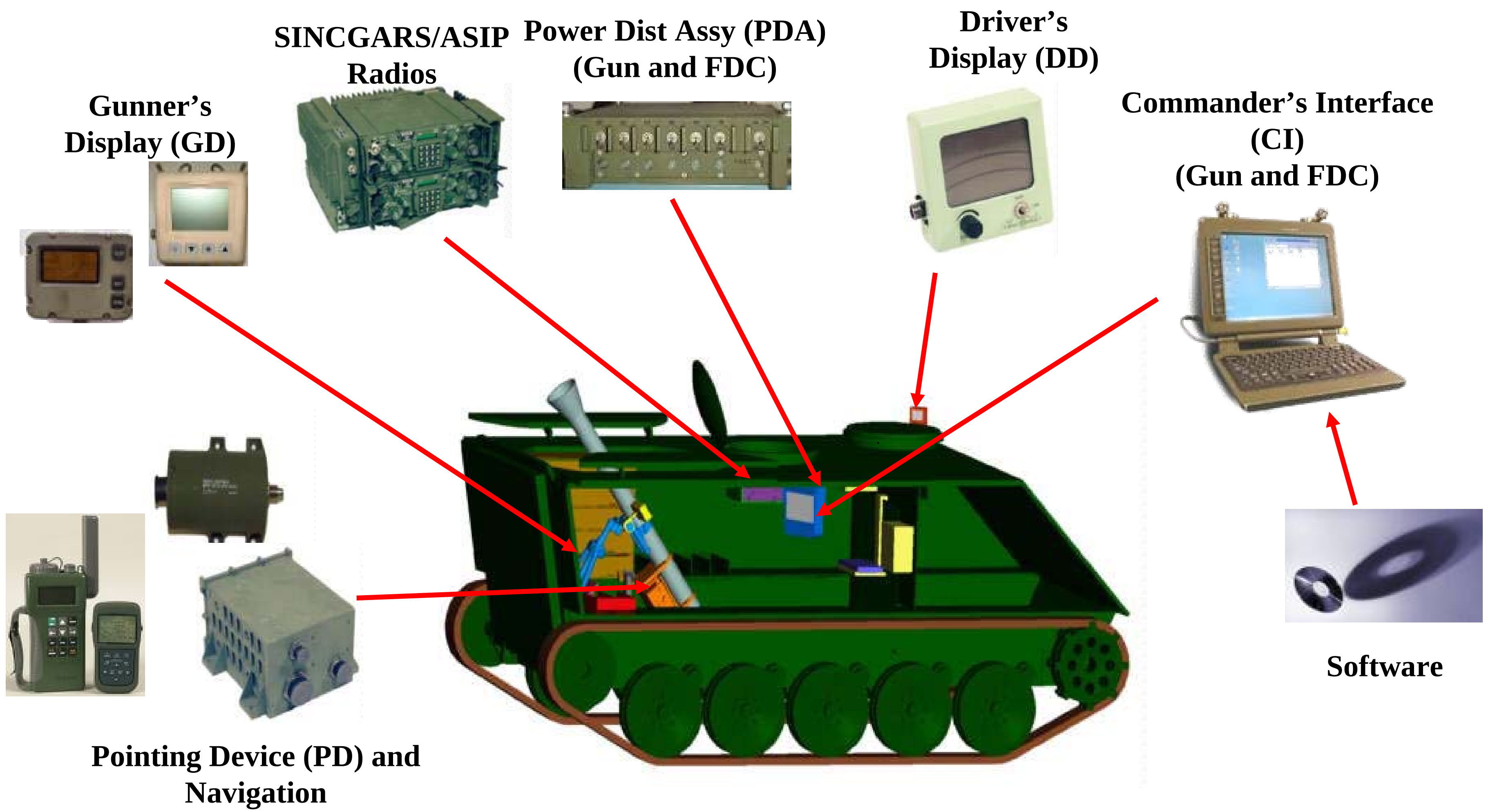
- ARDEC
- PM Mortars
- Honeywell
- BAE
- Milpower
- KVH
- DRS
- GRC

M95/M96 System Overview

- Provide digital fire control capability for Mortar Carrier Vehicles (M1064, M577, STRYKER)
- Digital connectivity with AFATDS
- 4 mil Azimuth and 3 mil elevation pointing accuracy
- No crew dismount
- Ballistic calculations within 10 seconds

US ARMY RDECOM

M95/M96 Mounted (Legacy) System



Malcolm Baldrige National Quality Award 2007 Award Recipient

New M150/M151 Dismounted System

MFCS Dismounted is a mortar fire control system for the 120mm mortar weapon system. It is integrated into the Quick-Stow trailer, which was designed to lower and lift the weapon.

M150/M151 System Overview

- Provide digital fire control capability for Dismounted 120mm Mortar Units
- Digital connectivity with AFATDS
- 4 mil Azimuth and 3 mil Elevation pointing accuracy
- Ballistic calculations within 10 seconds
- Integrated with Quick-Stow system for easy emplacement and displacement of weapon

M150 Gun System Design

Fire Control Computer
(FCC)

Enhanced Power Distribution Assy
(EPDA)

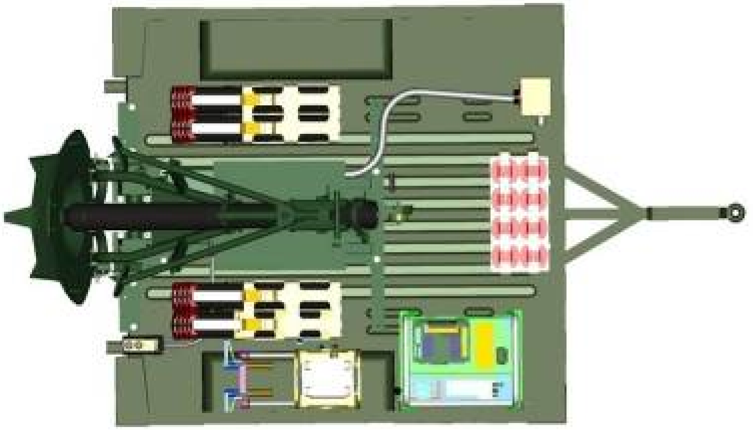
DAGR (GPS)

ASIP Radio

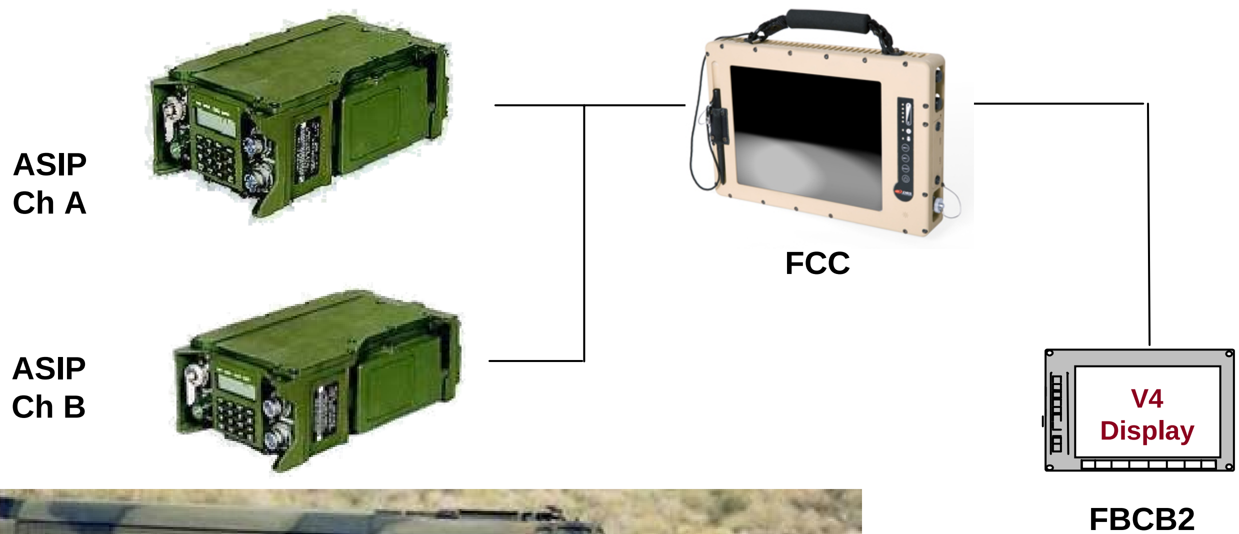
Pointing Device Mount
Assembly (PDMA)

Fire Control Display
(FCD)

Portable Universal Battery Supply
(PUBS)



M151 FDC System Design



Innovation Highlights

- Replacement of Legacy Computer
- Power Distribution / Communication Upgrade
- Driver and Gunners Display
- PDMA
- System Cables
- Configuration (Modular E-Rack & HMMWV Mount)

Replacement of Legacy Computer

CI

FCC

- Introduction of Resistive Touchscreen
- 18.6lbs vs. 7.8lbs
- Increased computing power (faster processor, more memory)
- Smaller footprint
- ~$6K cost reduction per unit

Power Distribution & Communication Upgrade

PDA

E-PDA

- E-PDA adds internal Ethernet / Serial Hub
  - Allows Ethernet to serial LRU communication
  - Ethernet communication simplifies and reduces cabling
- Includes additional power ports for growth
- E-PDA is backwards compatible with M95/M96 System PDA to allow for drop-in replacement

Driver and Gunners Display

GD

DD

FCD

- New display can work as GD or DD
  - Reduces logistics footprint
  - Commonality
- FCD is backwards compatible with M95/M96 GD and DD to allow for drop-in replacement
- Improved sunlight readability over current GD
- ~8K Reduction in Cost for GD

PDMA

- Isolates PD from mortar fire shock and vibration
  - Utilizes novel slide rail approach
  - Allows for use on more severe ground mount configuration
- Quick-Release feature
  - Allows PD to be dismounted quickly during misfires and after completion of mission

System Cables

- M150/M151 cables are triple shielded
  - 2 layers of tin-copper braid with a layer of foil in between
  - Meets higher shield attenuation levels
- Backshells and transitions are molded
  - Increases durability
  - Allows for ease of cable routing
  - Cable attachment points can be molded in

Modular E-Rack & HMMWV Mount

- Fire control system is mounted in a modular rack
  - Allows system to be mounted on the ground
  - Allows ease of movement of multiple LRU’s
- HMMWV equipped with flip down FCC mount
  - Allows FCC to be operated while vehicle is moving
  - FCC clips in and out between E-Rack and passenger location

Conclusions

- M150 / M151 Delivers new capabilities to the war fighter
- Design increases modularity and reduces logistic footprint
- M150/M151 increases the flexibility of the war fighter
- M150/M151 allows for development in other weapon systems

Video and Questions

Thank you for coming to our briefing,

Amit and Ralph

BACKUP SLIDES

Commanders Interface (CI)

- Currently a modified COTS solution
- Runs Mortar Fire Control software
- User interface for system
- 1.6GHz processor, 5Gb solid state HDD
- 4 RS-422, 1 RS-232, USB, Ethernet
- MIL-1275 compliant 24VDC input
- Audio output
- Tactical modem with two-wire interface

Power Distribution Assembly (PDA)

- Accepts 24VDC input
- Conditions power and sends appropriate voltage to each LRU
- Main and individual circuit breaker / switch for each LRU

Driver's Display (DD) Assembly

- DD Assembly consists of:
  - DD (currently COTS solution)
  - Shock isolation hardware
  - RAM arm mount
- Displays vehicle direction and distance from emplacement position
- Mounted inside and outside of drivers compartment (M1064)

Gunner's Display (GD) Assembly

- GD Assembly consists of:
  - GD (currently COTS solution)
  - Shock isolation hardware
- Displays ammo info and software calculated pointing solution for gunner
- Mounted on back wall of track (M1064)

Pointing Device (PD) and Navigation

- TALIN™ 3000 manufactured by Honeywell Aerospace currently used
- Provides navigation and weapon pointing functionality
  - Initial position either manually entered or provided by DAGR handheld GPS
- Mounted in PDMA, which isolates PD from shock and vibration (1064 configuration only)

- PLGR or DAGR are use for GPS assist
- Vehicle Motion Sensor is used for vehicle speed assist

Fire Control Computer (FCC)

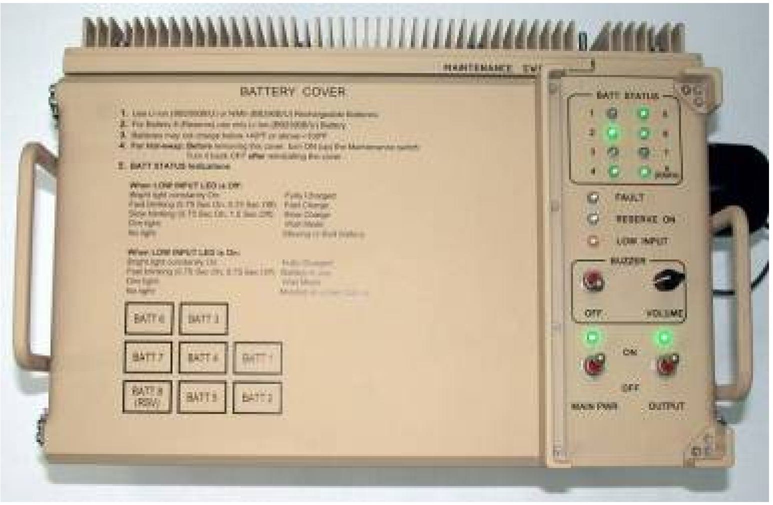
- Currently a modified COTS solution
- Runs Mortar Fire Control software
- User interface for system
- 10.4” resistive touch-screen
- 1.1GHz processor, 1Gb RAM, 8Gb solid state HDD
- 4 RS-422, 1 RS-232, USB, Ethernet
- MIL-1275 compliant 24VDC input
- Audio output
- Tactical modem with two-wire interface
- Glenair Mighty Mouse mini rotating connectors used
- Mounted in HMMWV passenger side when moving and is hand-held or mounted on e-rack during firing operations

Enhanced Power Distribution Assembly (EPDA)

- Accepts 24VDC input from PUBS or any NATO source
- Conditions power and sends appropriate voltage to each LRU
- Main and individual circuit breaker / switch for each LRU
- Internal 4-port Ethernet switch and Ethernet-serial server that allows for 4 virtual RS-422/RS-232 serial ports
- In MFCS Dismounted, acts as commo link between FCC and LRUs
  - FCC connects to EPDA via ethernet
  - LRUs connect to EPDA via serial
- Mounted on E-Rack

Portable Universal Battery Supply (PUBS)

- Main power source for MFCS Dismounted
- 8 user swappable batteries
  - 1 is semi-permanent “reserve” to prevent catastrophic system shutdown
- Accepts BB2590, BB390 (A and B), BA5590 batteries already in Army inventory and widely used
- Individual LEDs provide status and diagnostics for each battery
- Fault LED
- Audible Alarm with volume control sounds when reserve battery is in use
- Currently best system runtime using PUBS is ~10 hrs. using BB2590s at ambient
- Mounted on E-Rack



Electronics-Rack (E-Rack)

- Mounted in front curbside of trailer
  - Can stay in trailer or be dismounted during firing operations
- Holds ASIP, EPDA, PUBS, DAGR
  - Currently holds GD assy when moving, but a new location for the GD assy on the trailer body itself has been selected
- For convenience includes mount to hold FCC during firing operations
- Swings open to allow access to PUBS for battery swapping

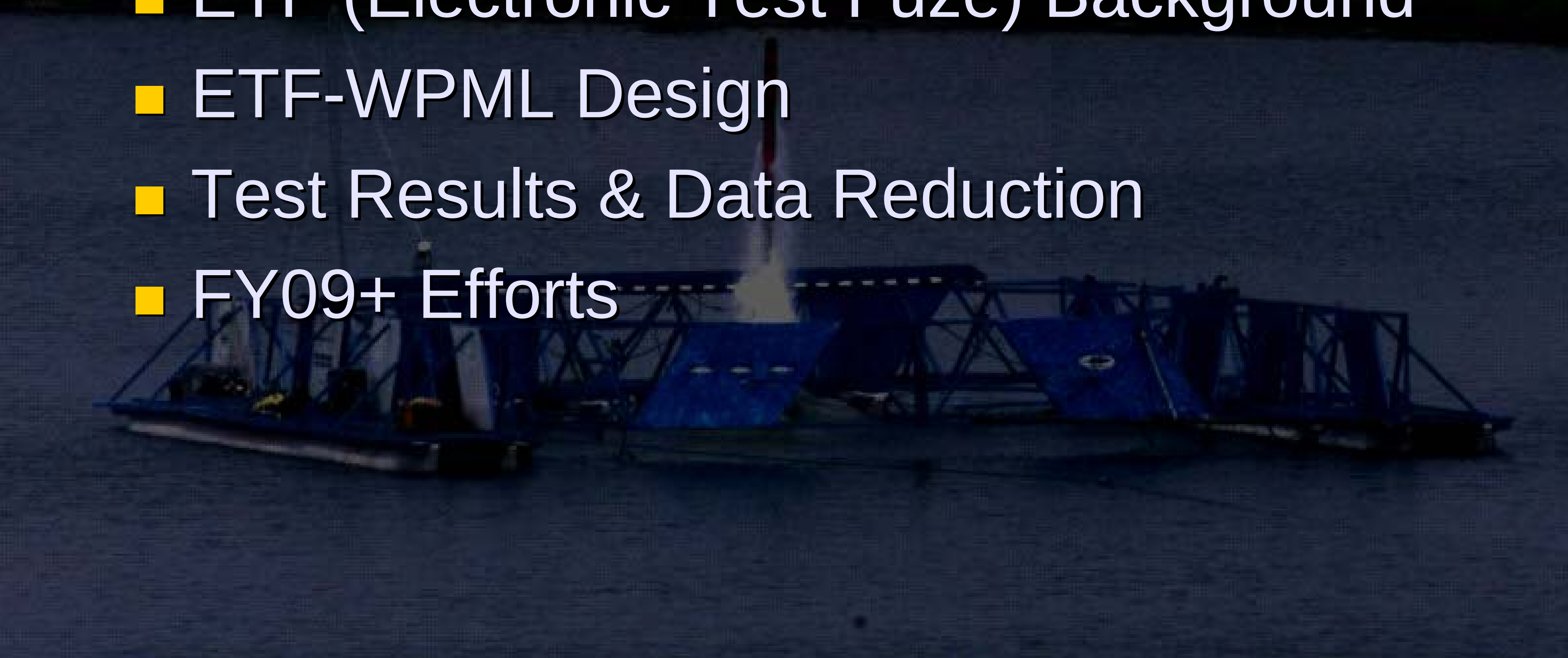
ETF-WPML Instrumented Projectile

Michael Irwin
Naval Surface Warfare Center Dahlgren Division
michael.g.irwin@navy.mil
Guns & Missile Systems Conference
8 April 2009

DISTRIBUTION STATEMENT A.
Approved for public release;
distribution is unlimited.

Overview

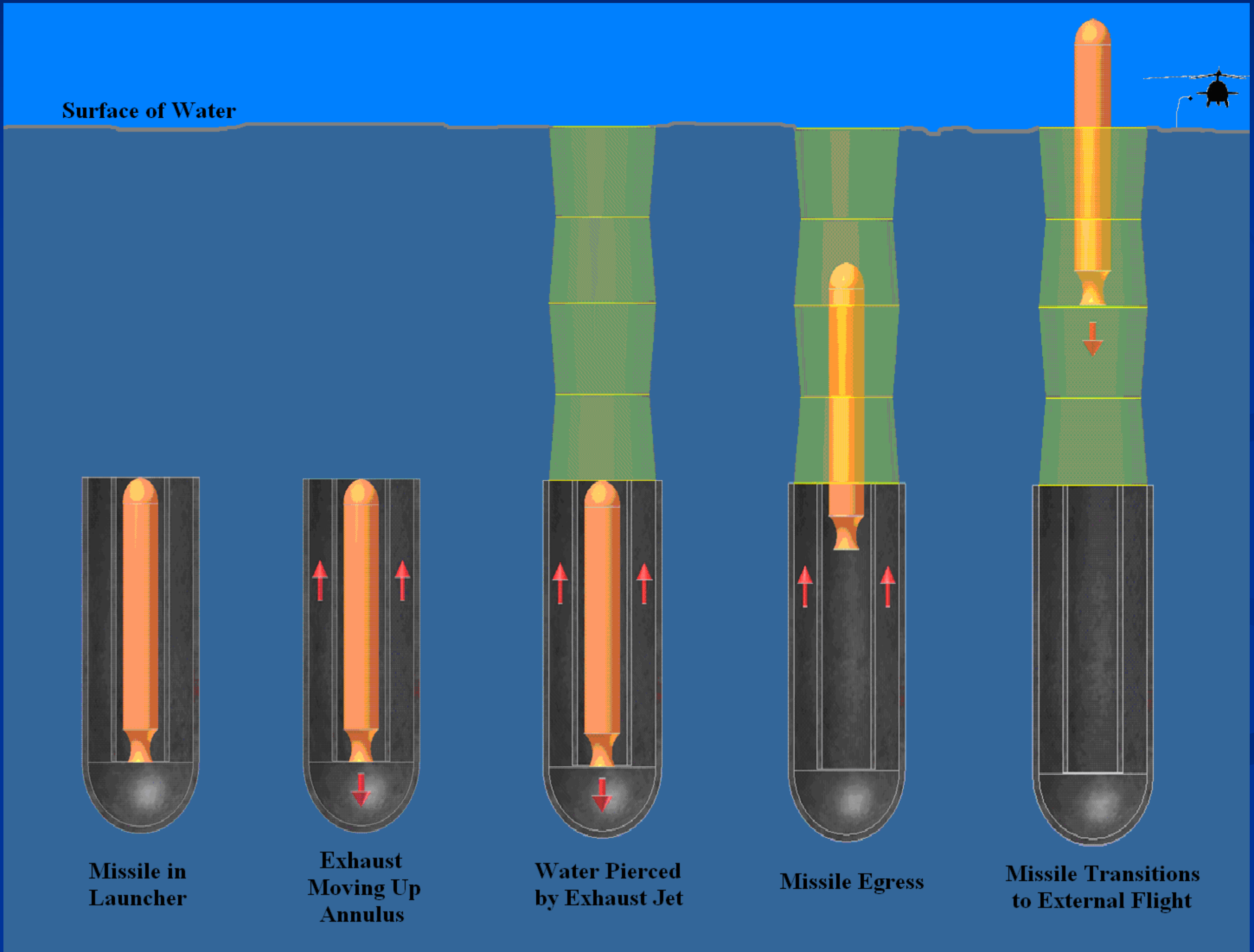
- WPML (Water Piercing Missile Launcher) Overview
- ETF (Electronic Test Fuze) Background
- ETF-WPML Design
- Test Results & Data Reduction
- FY09+ Efforts



WPML Concept

DISTRIBUTION STATEMENT A

CCL
(Concentric Canister Launcher)



The Need for On-board Instrumentation

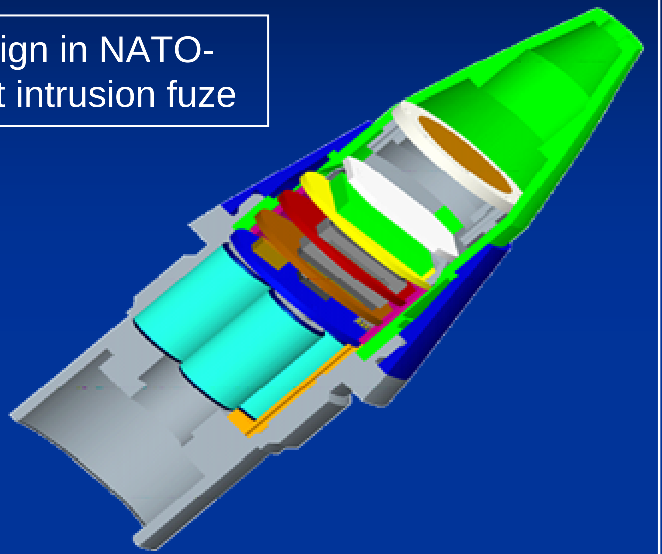
- Measure the missile's shock and vibration levels before release and in the plume
- Identify possible missile contact with water in the plume
- Identify possible tail slap during water exit
- Characterize the missile's rigid body motion

All of these require on-board instrumentation!

DISTRIBUTION STATEMENT A

ETF – Electronic Test Fuze

Core ETF design in NATO-standard short intrusion fuze



Key Events / Milestones

Flight	Projectile	Charge	Location	Date	Met Objectives
ETF 1	155mm	7W	AA Fuze	8/06	Y
ETF 2 (IR link)	155mm	7W	AA Fuze	11/06	Y
ETF-GPS 1	155mm	7R	AA Fuze	4/07	Y
ETF-GPS 2	155mm	7R	AA Fuze	8/07	Y
ETF-ERGM 1-5	ERGM	EX167	WSMR	2/08	Y
ETF-GPS 3-4	155mm	7R	AA Fuze	5/08	Y
ETF-WPML 1	Missile Body	N/A	Crane	8/08	Y
ETF-WPML-2	Missile Body	N/A	Crane	11/08	Y

- Designed fully in-house at NSWCDL, G-33 (Precision & Advanced Systems Branch)
- Designed to support realistic gun-shock testing of myriad subsystems
- 1.5” O.D. Board Stack
- On-board sensors include a 3-Axis magnetometer and an axial 20 kG accelerometer
- 1 Mbps Telemetry Encoder, ½ Watt S-Band Telemetry Transmitter
- Easily configurable to support additional sensors or subsystems
- Designed and tested for 50kG shock survival
- All-up system successfully flight tested
  - 5-for-6 gunshots out of 155mm Howitzer to 9 kG
  - 4-for-5 ERGM flight tests to 10+ kG
  - 8-for-8 High-G tests
  - 2-for-2 WPML Instrumented Missile tests
- Core Stack with telemetry fits in NATO standard fuze form factor
- Costs including all HW, ME/EE Support, and data breakout
  - ~$10,000/per, basic ETF
  - +$1500/per ETF w/ low frequency, high-G triax accel
  - +$6,000/per ETF w/ high frequency, high-G triax accel

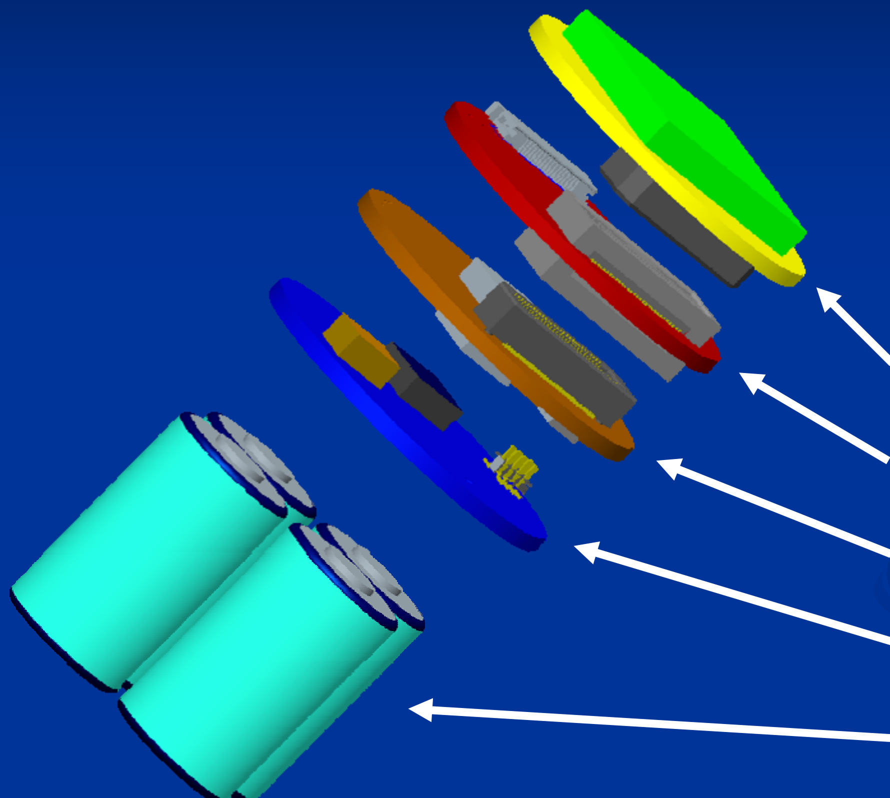
Sponsors: GIF, ERGM, WPML, others

Team Lead: Hamish Malin, G-33

Dahlgren Team: Marc Bassett, Michael Irwin, Travis James, Nathan Joswiak, and others depending on project

DISTRIBUTION STATEMENT A

Board Stack - General



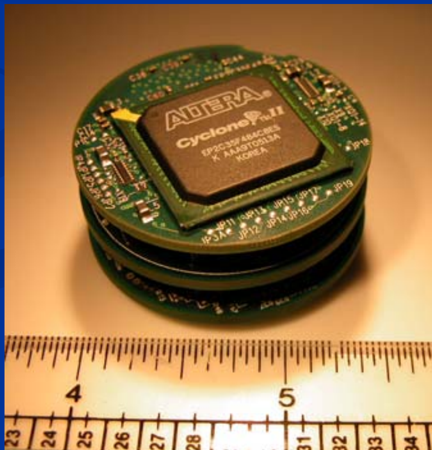
FPGA Board

FPGA I/O Support Board

Sensor Board

Power Board

Batteries



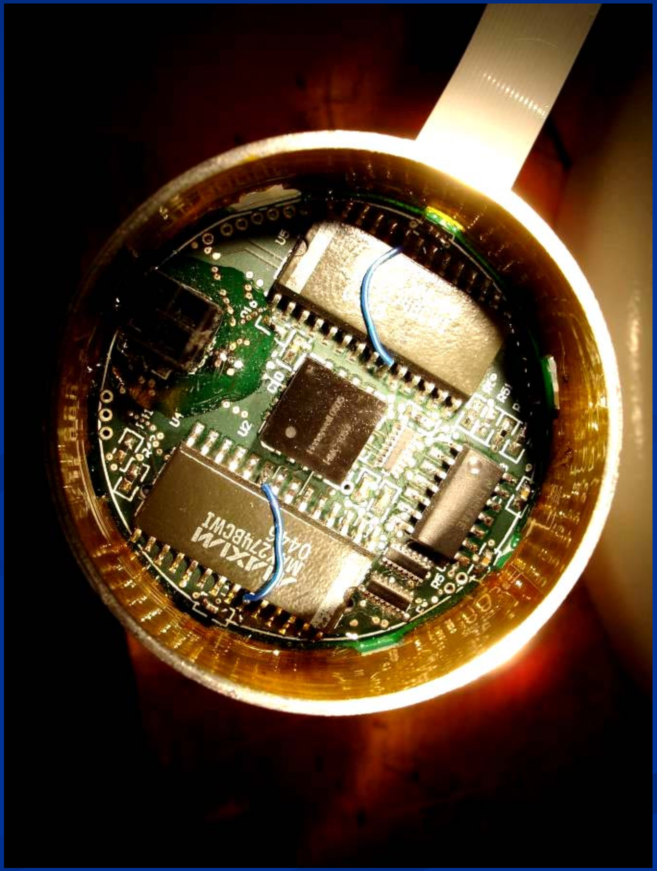
FPGA Board

- Interfaces with ADCs and sensors
- Controls & monitors various subsystems under test
  - HOB sensor
  - ElectRelease actuator
  - IR transceivers
  - GPS Rx
- Measures (time = 0) from forward-looking accelerometer
- Encodes test data into telemetry stream

FPGA architecture makes ETF adaptable for future tests

Sensor Board

- Silicon Designs 20k-g 1-axis accelerometer
- Honeywell HMC 1053 3-axis magnetometer
- 2 Maxim MAX274 8th-Order Active Filters provide 2nd-Order Chebyshev LPF for each channel
- 2 12-bit, 8-channel TI ADS7852 ADCs sample at up to 32 ksps

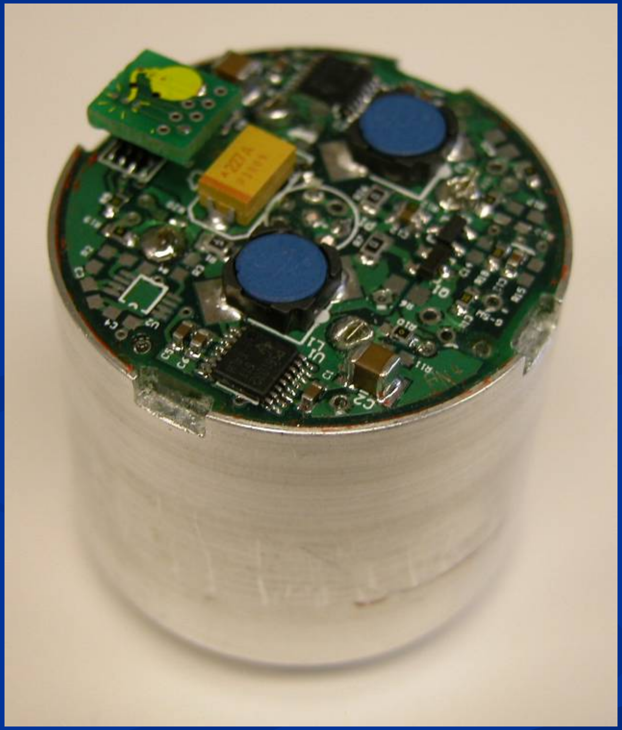


Vias available for additional external sensors

DISTRIBUTION STATEMENT A

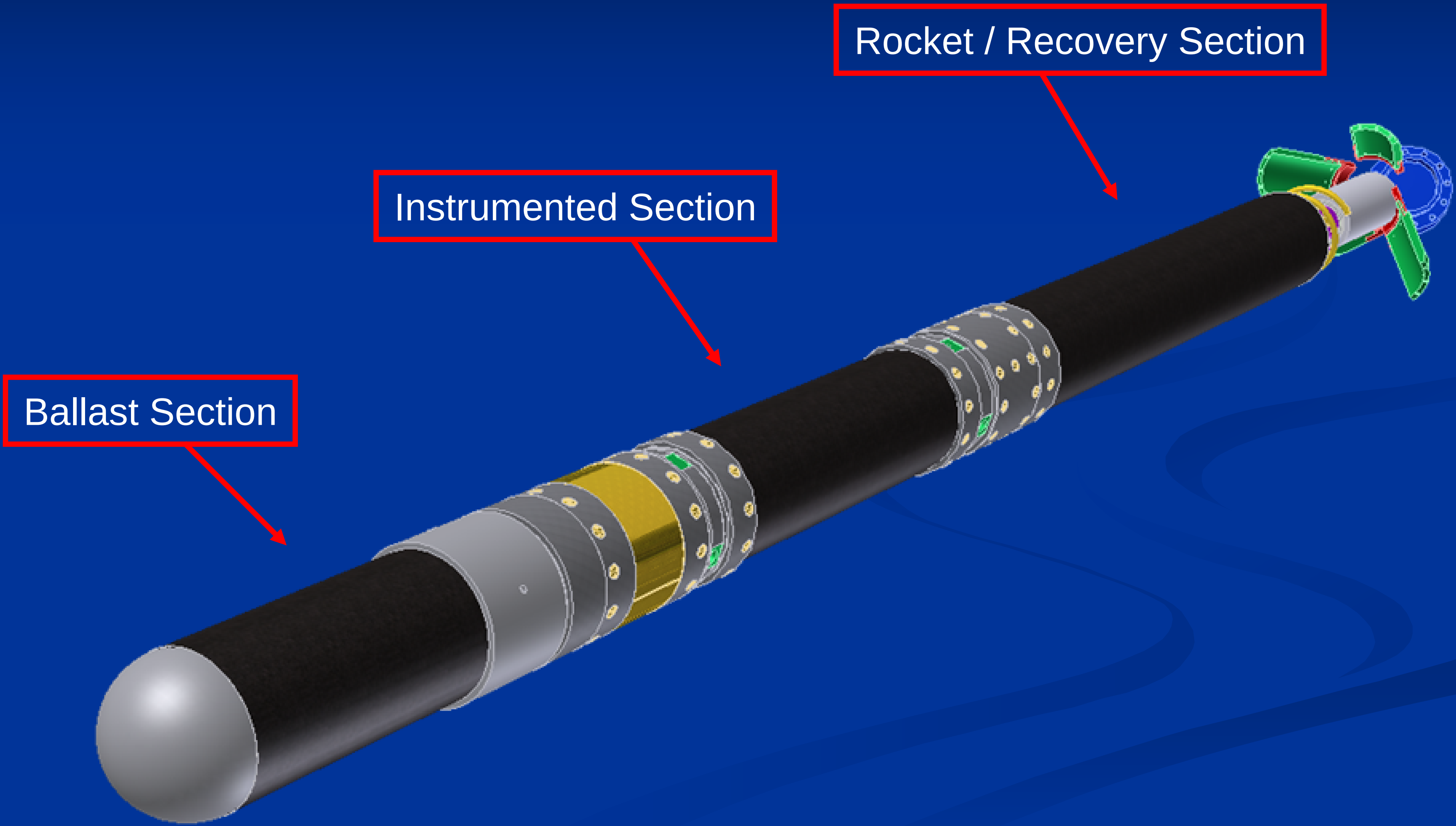
Battery Puck & Power Board

- Current configuration utilizes 4 CR2s
- Puck is designed to be removable such that fresh batteries can be used for flight
- Supplies 5V, 2A; 4V, 500mA
- Other voltages possible
- Current puck can power full ETF stack for > 2hrs



DISTRIBUTION STATEMENT A

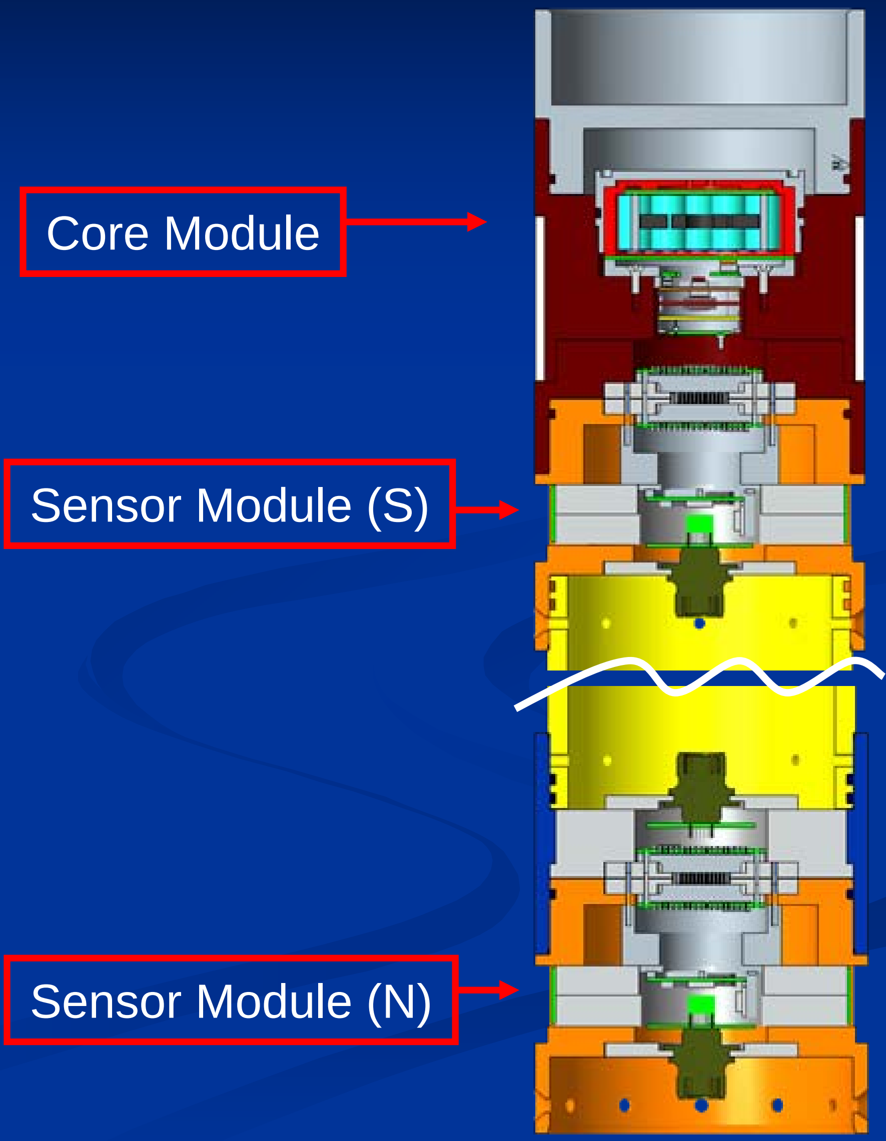
Projectile Overview



DISTRIBUTION STATEMENT A

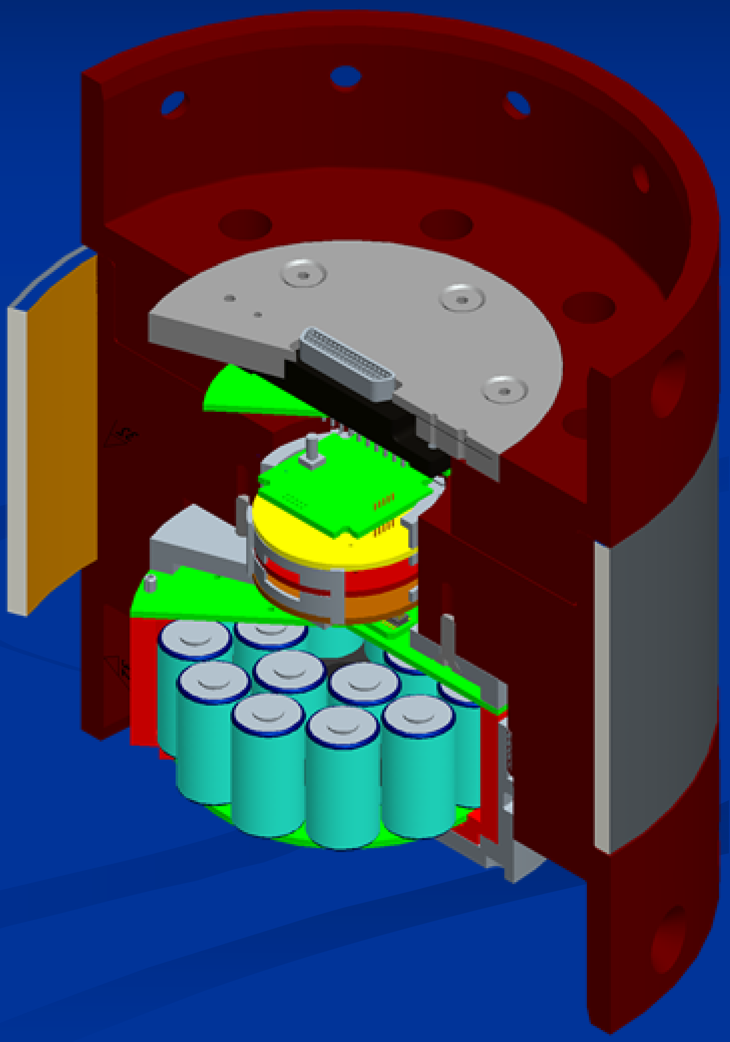
ETF-WPML Overview

- 1 core module, 2 sensor modules
- Core module has axial accelerometer
- Sensor modules have 3-axis accelerometers and moisture sensors



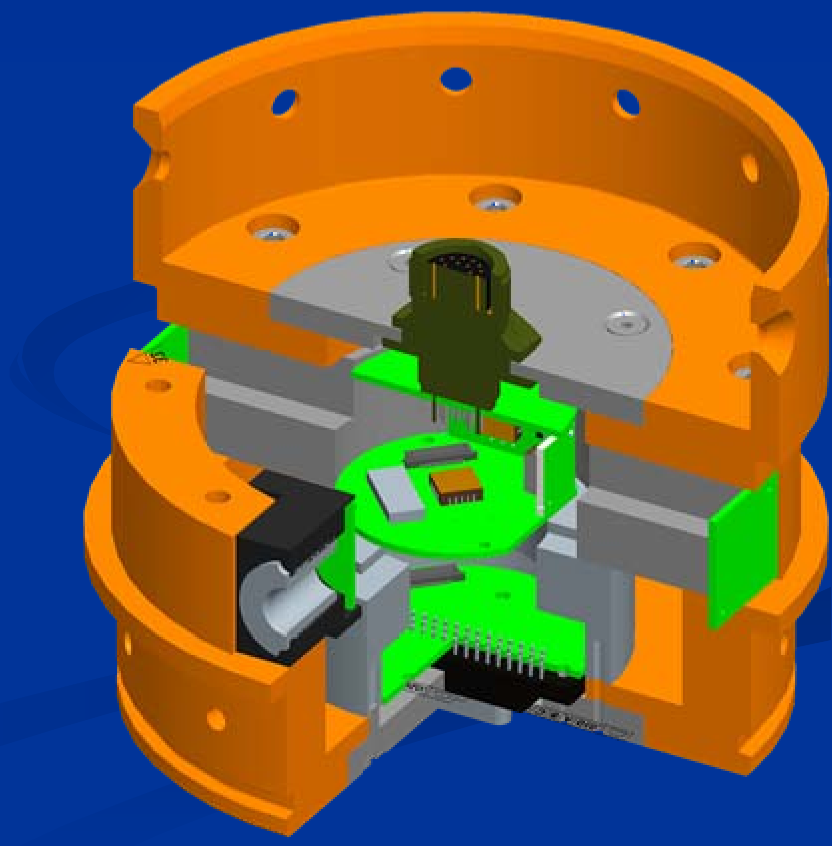
Core Module

- Core Module
  - Transmitter: MA06836-025
    - 2254.5 MHz, 500mW FM telemetry transmitter
    - Fired on M549 RAP, M795, M483, ERGM
  - “Core Stack”
    - FPGA Board
    - Support Board
    - Sensor Board
  - Power Module
    - Energizer CR2 Lithium Batteries
    - Similar assemblies fired on 155mm ammo up to 16 kG and 5” ERGM



Sensor Module

- Accelerometer Suite
  - 3x single axis sensors oriented in three primary axes
  - +/- 200G Max/Min Amplitude
  - 4 kHz sample rates
  - Anti-aliasing filters tuned to pass DC - 2kHz
- Water Sensors
  - 2x recessed, 2x on surface
  - Each element registers pass/fail
  - 1 kHz sample rates
  - Disabled on North module



Translator

- Gondola supports CCL and missile underwater
- Translator supports gondola
- Translator is towed by boat to emulate submarine launch conditions

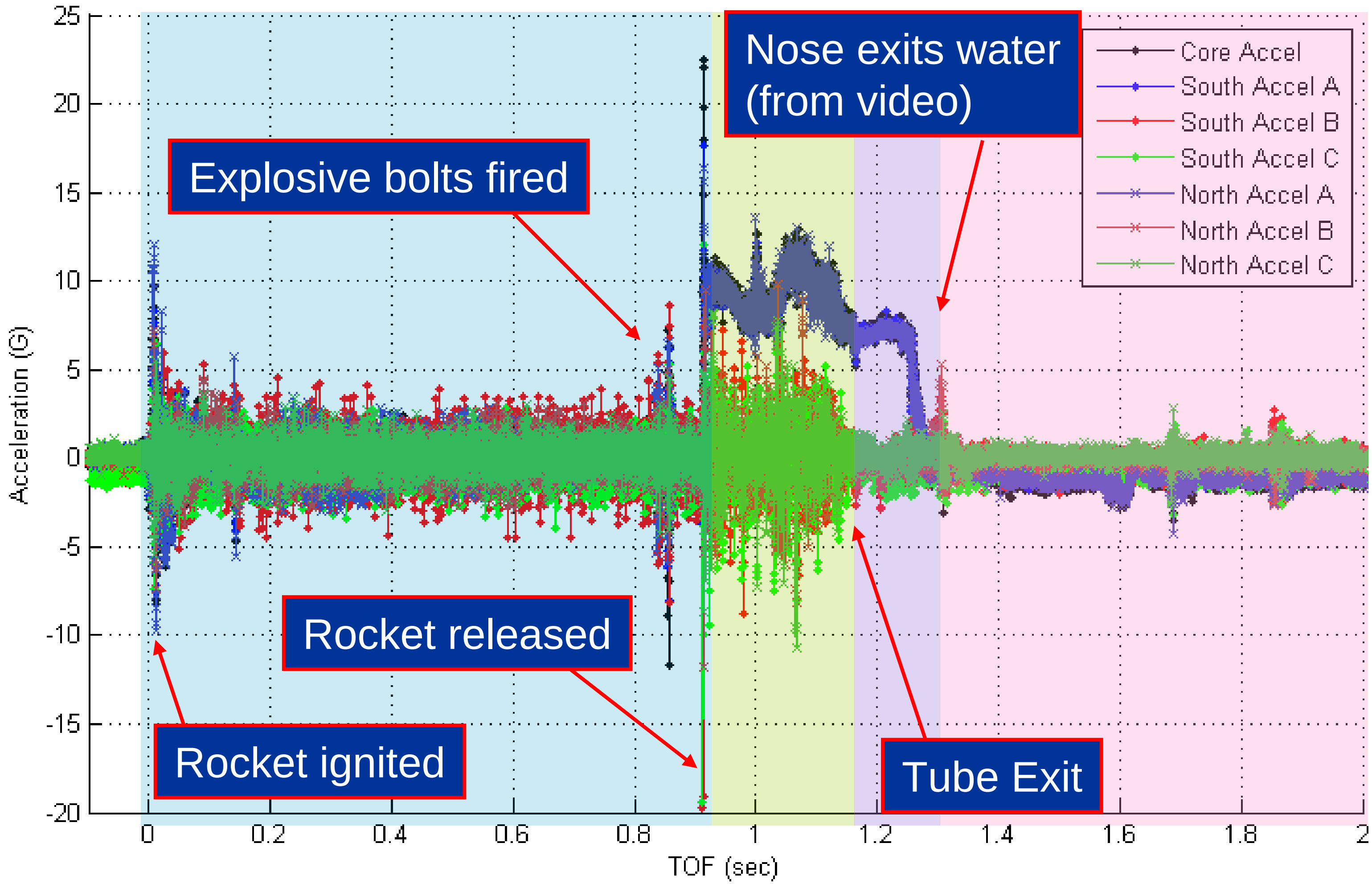
DISTRIBUTION STATEMENT A

Lake Glendora Instrumented Test Summary

- June 2008
  - Did not launch (No test)
- August 2008 – 1 knot flyout
- November 2008 – 3 knot flyout

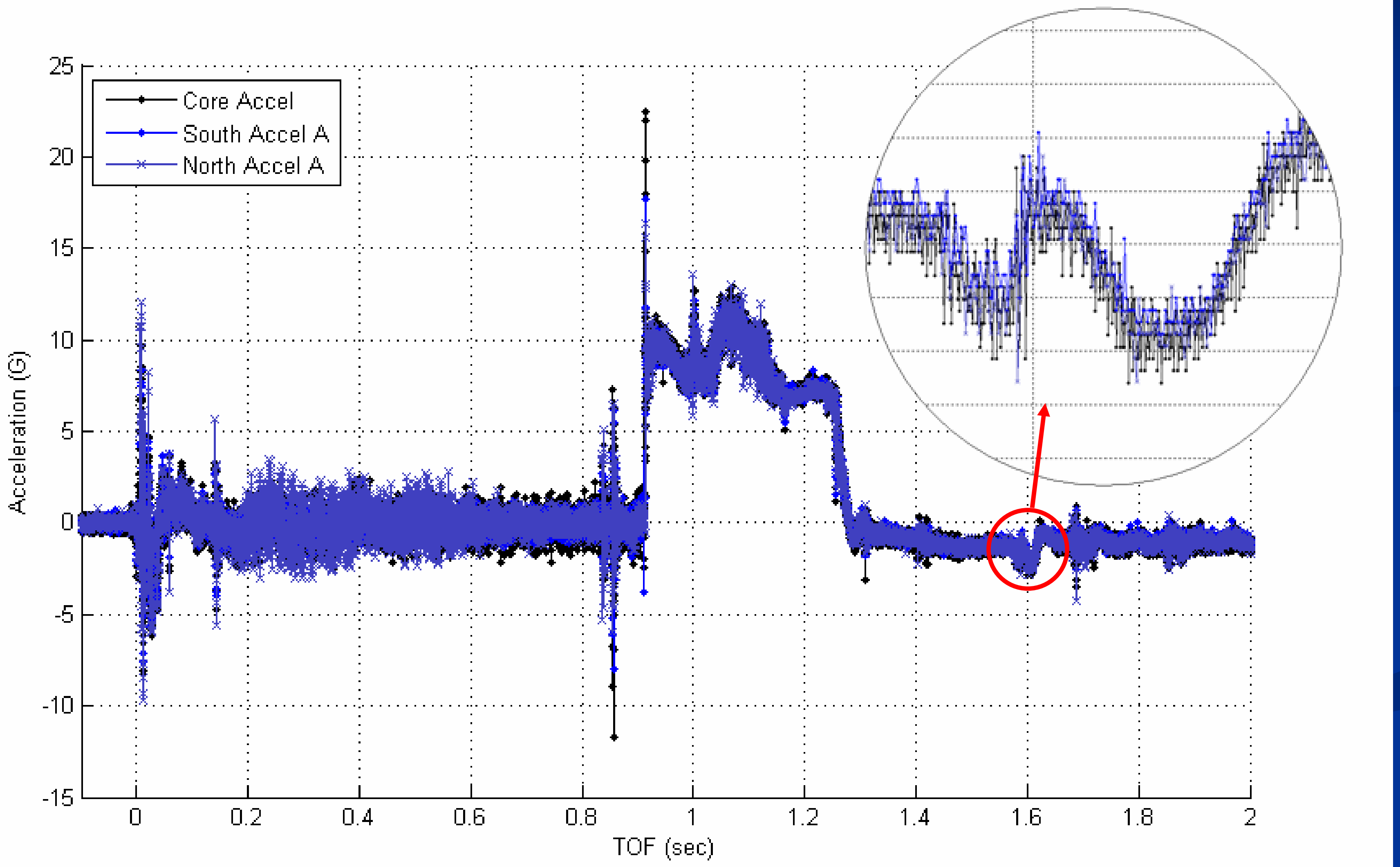
DISTRIBUTION STATEMENT A

Accelerometer Data



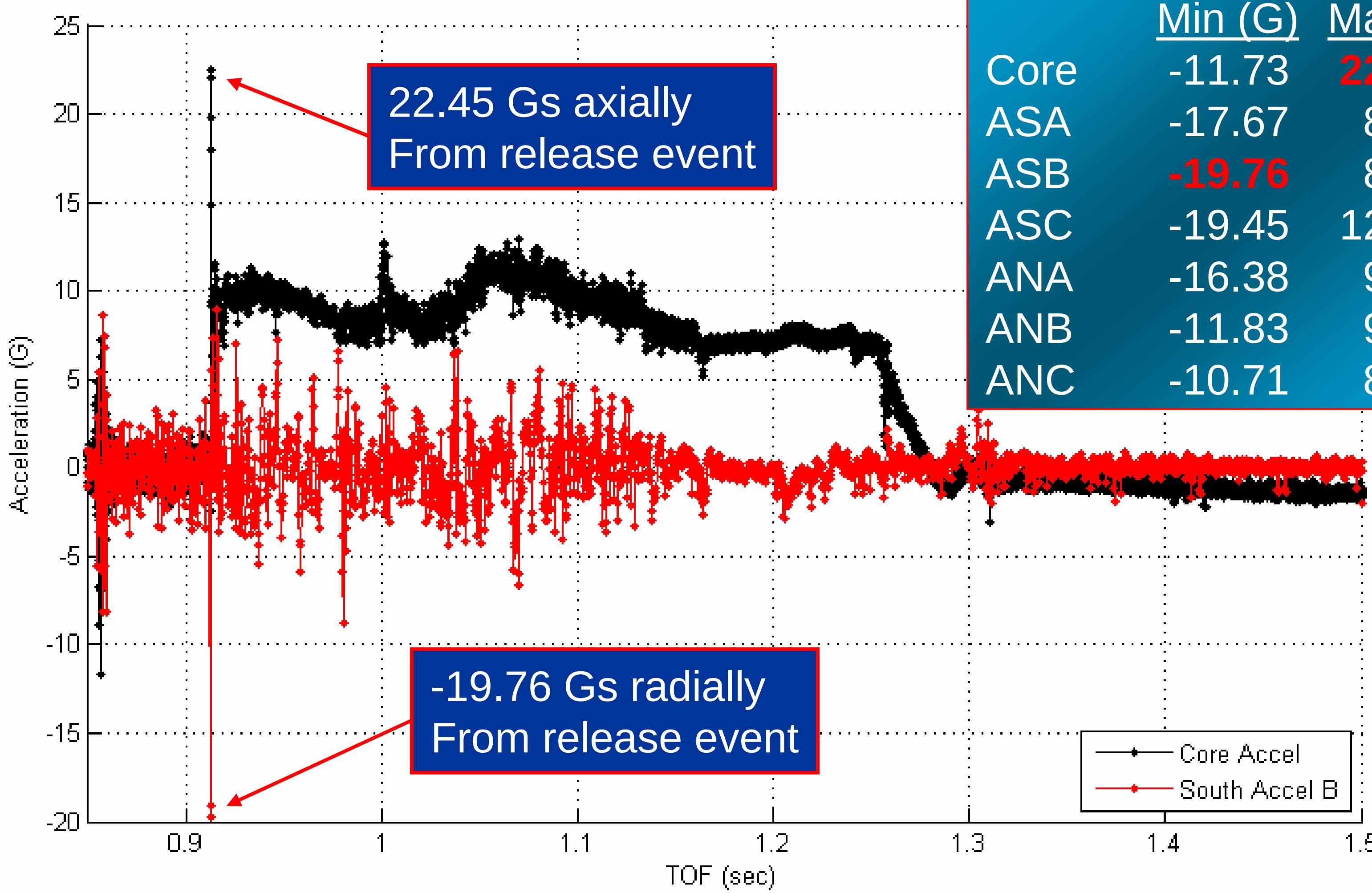
DISTRIBUTION STATEMENT A

All three axial accels



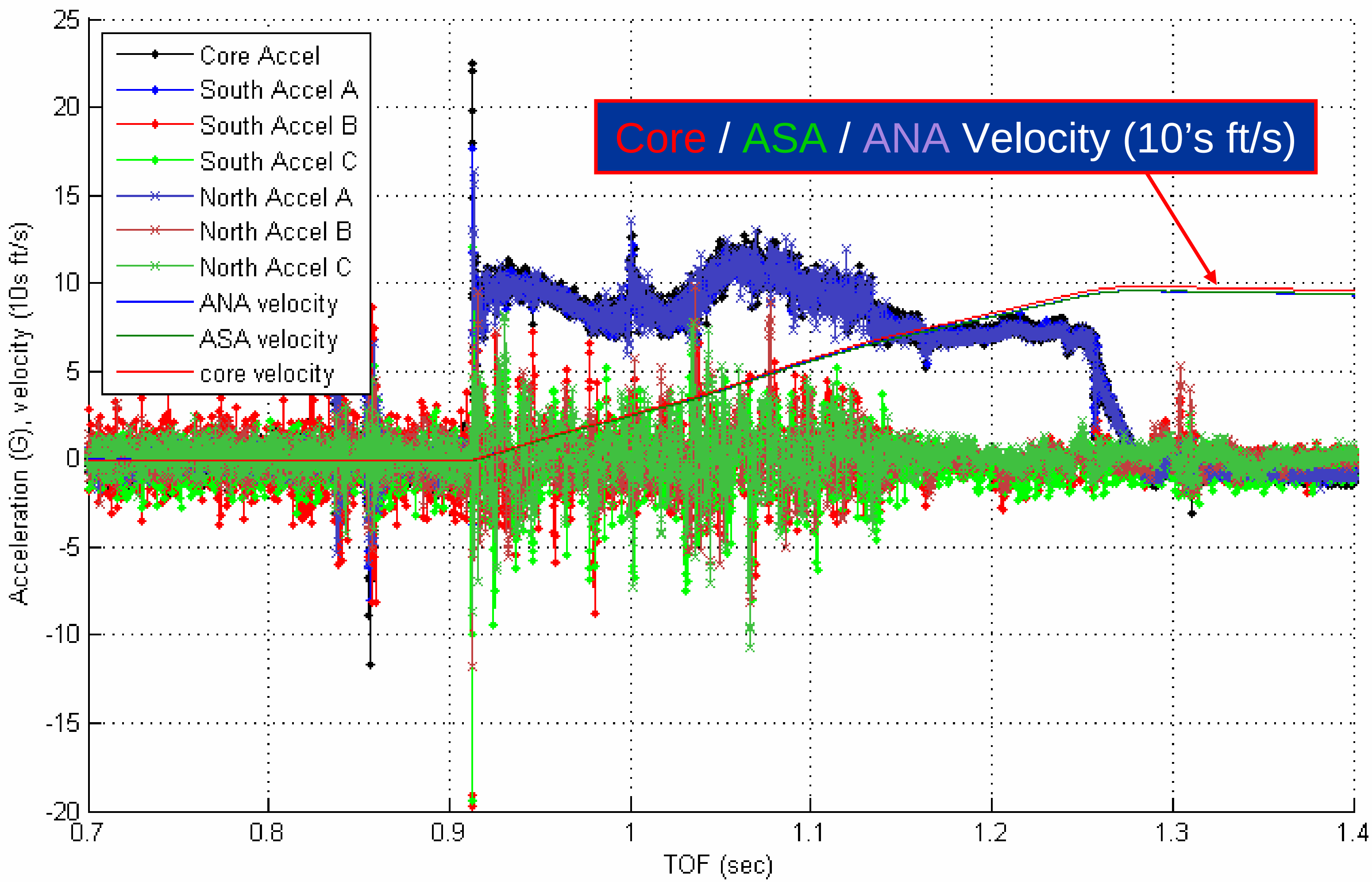
DISTRIBUTION STATEMENT A

Maximum Measured Loads

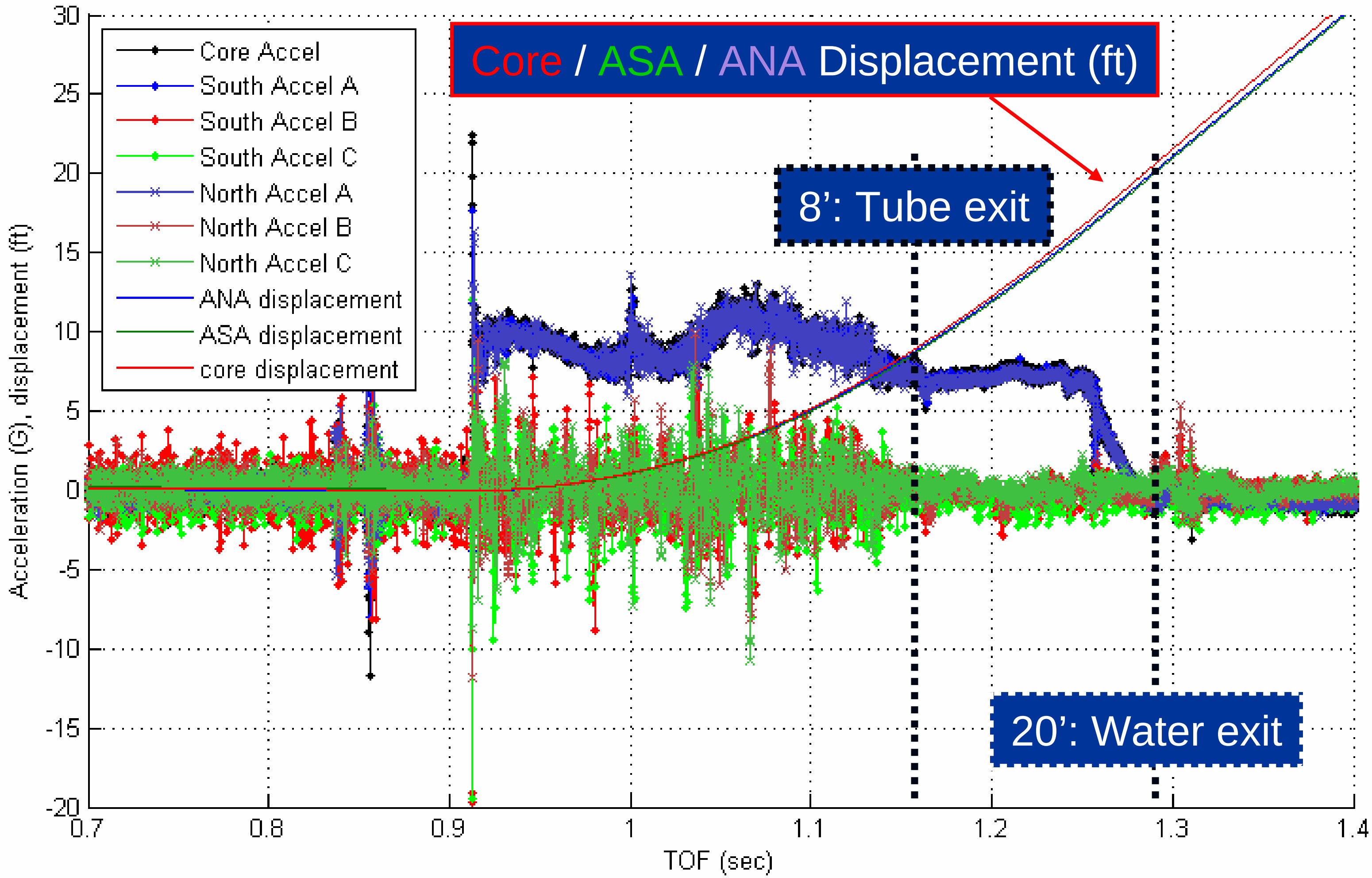


	Min (G)	Max (G)
Core	-11.73	22.45
ASA	-17.67	8.00
ASB	-19.76	8.94
ASC	-19.45	12.00
ANA	-16.38	9.72
ANB	-11.83	9.84
ANC	-10.71	8.14

Axial Velocity

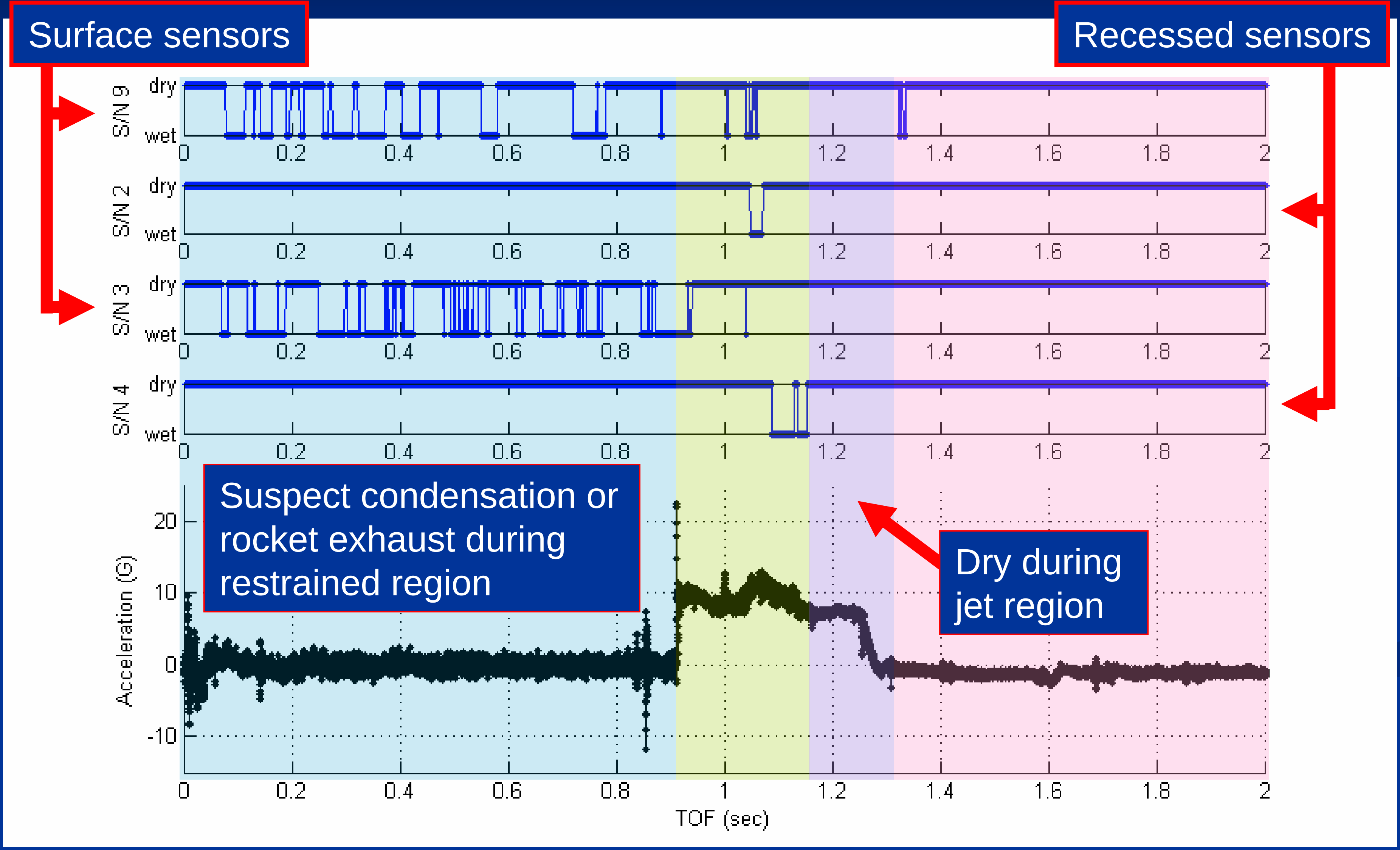


Axial Displacement



DISTRIBUTION STATEMENT A

Moisture Sensors Overlay



ETF-WPML Summary

- ETF-WPML developed in-house, on-budget, and on-schedule
- Instrumented section survived and collected data as planned
- Hardware has been reused for multiple tests, and will be used again for future tests
- Data collected has helped both validate predictions and confirm overall launch survivability
- Sensors processed for rigid body motion; more sensitive parts required for complete 6DOF solution

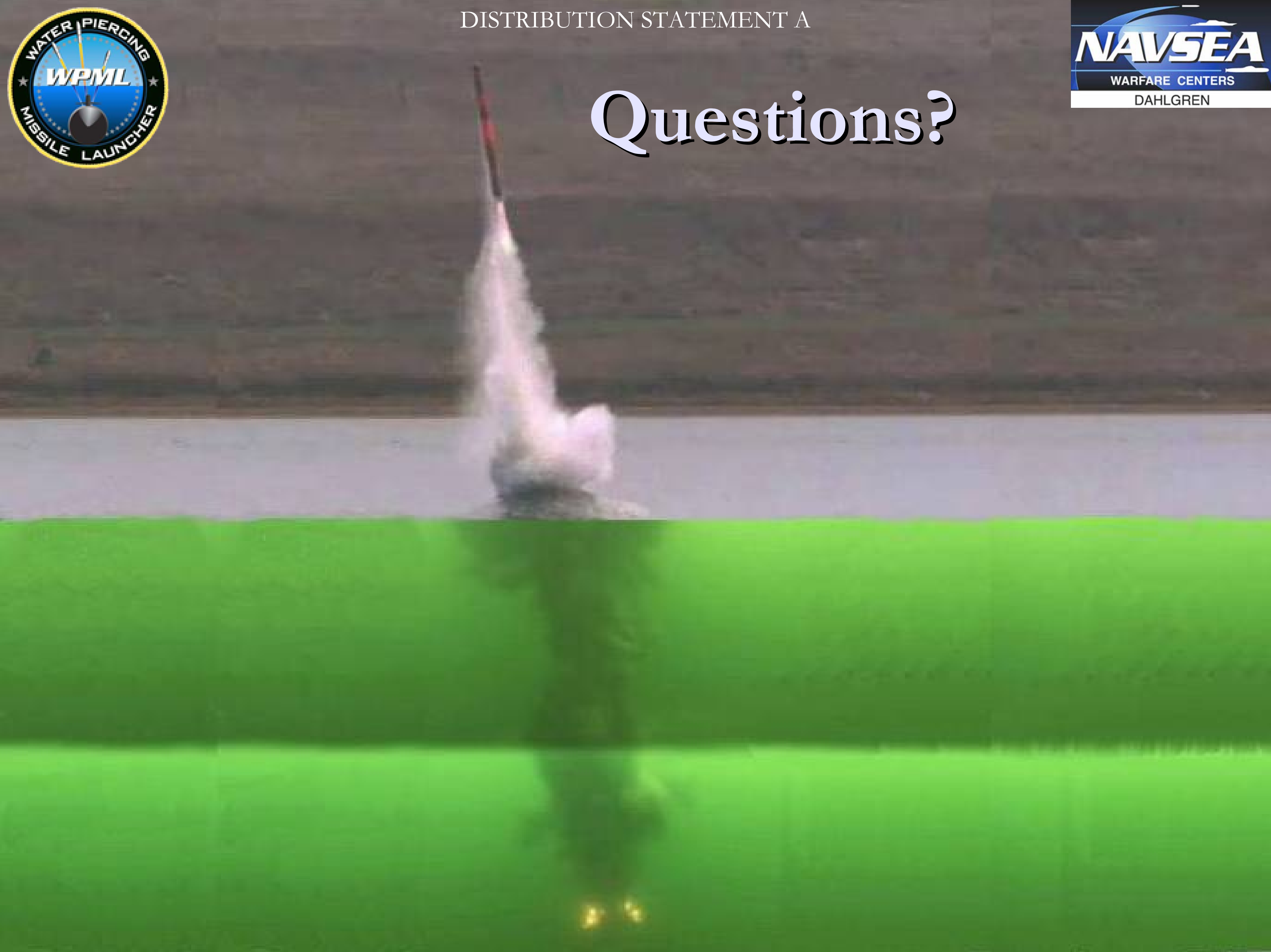
FY09 Work & Beyond

- FY09 tasks funded and moving forward
  - Attempt to instrument restrained shots
  - Port design into Sidewinder missile (ETF-SWR)
    - leverage legacy EE design
    - Integrate additional pressure & temperature sensors
      - Sensor requirements matrix currently being finalized
  - Develop on-board camera system to evaluate Sidewinder AIM-9X dome performance through egress
    - Camera down-selection currently underway
    - May incorporate telemetry, an on-board recorder, or both
    - Provides risk reduction prior to test with all-up AIM-9X
    - May provide additional insight into complex flow dynamics
  - Flight testing and data reduction for ETF-SWR and AIM-9X dome
- FY10+ possible tasking
  - Support at-sea flight testing with ETF-SWR
  - Instrument sub-scale models for laboratory testing

Credits

- WPML Sponsors
  - NAVSEA 073R (Undersea Technology Program Office)
  - PMS-450 (Virginia Class Program Office)
  - SSP (Strategic Systems Program)
- G64 (Integrated Weapons System Testing Branch) WPML Team
  - John Busic, Sam Koski, Dr. Jon Yagla
- G65 (Instrumentation Branch) Telemetry Support
  - Lin Conerly, Mike Weisman
- G33 (Precision and Advanced Systems Branch) ETF Team
  - Marc Bassett, Mike Irwin, Travis James, Nathan Joswiak, Hamish Malin

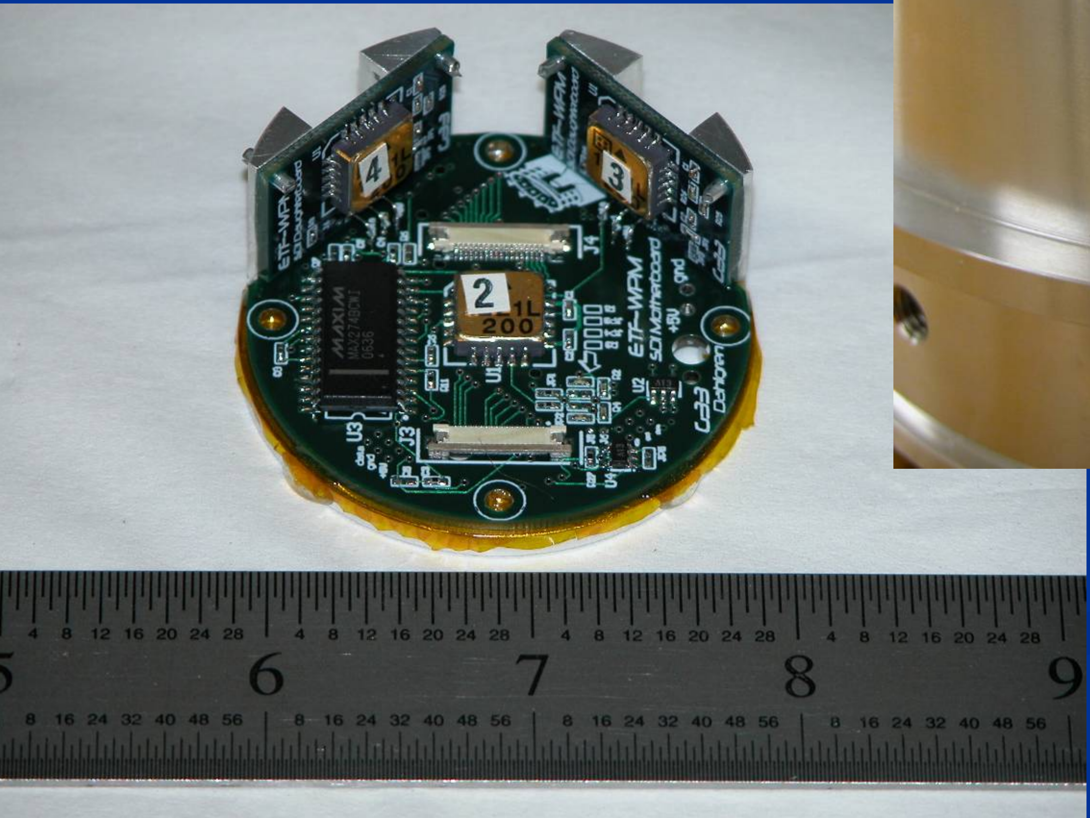
Questions?

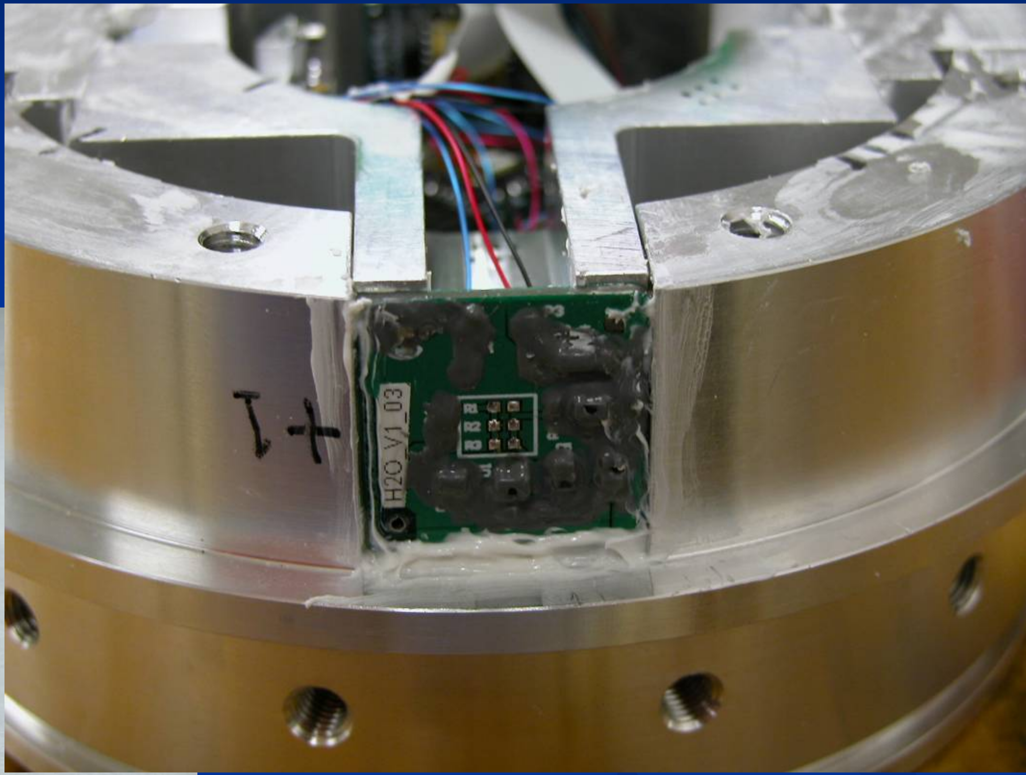


Backup Slides

Sensor Module details

3-axis accelerometer module

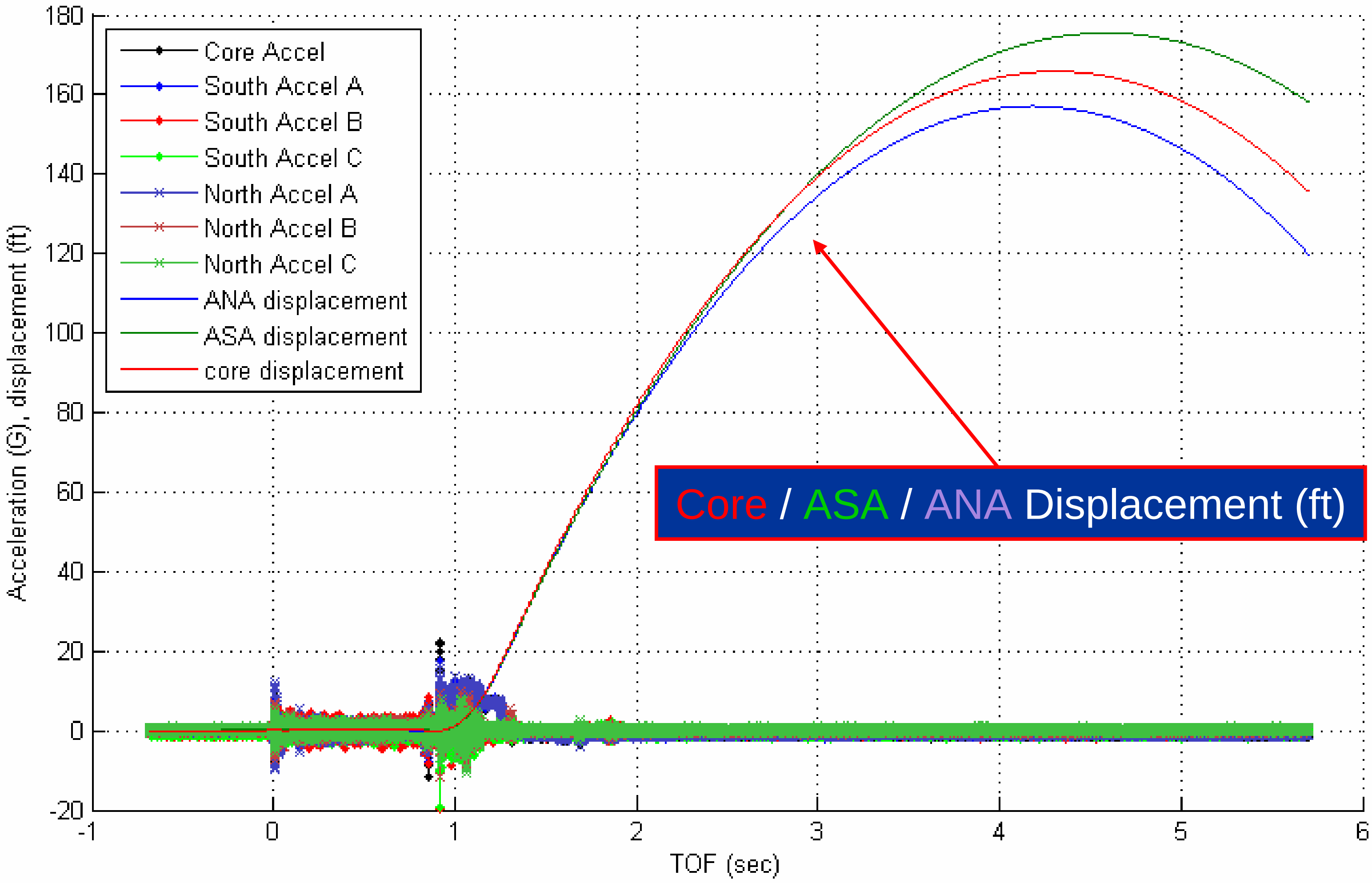




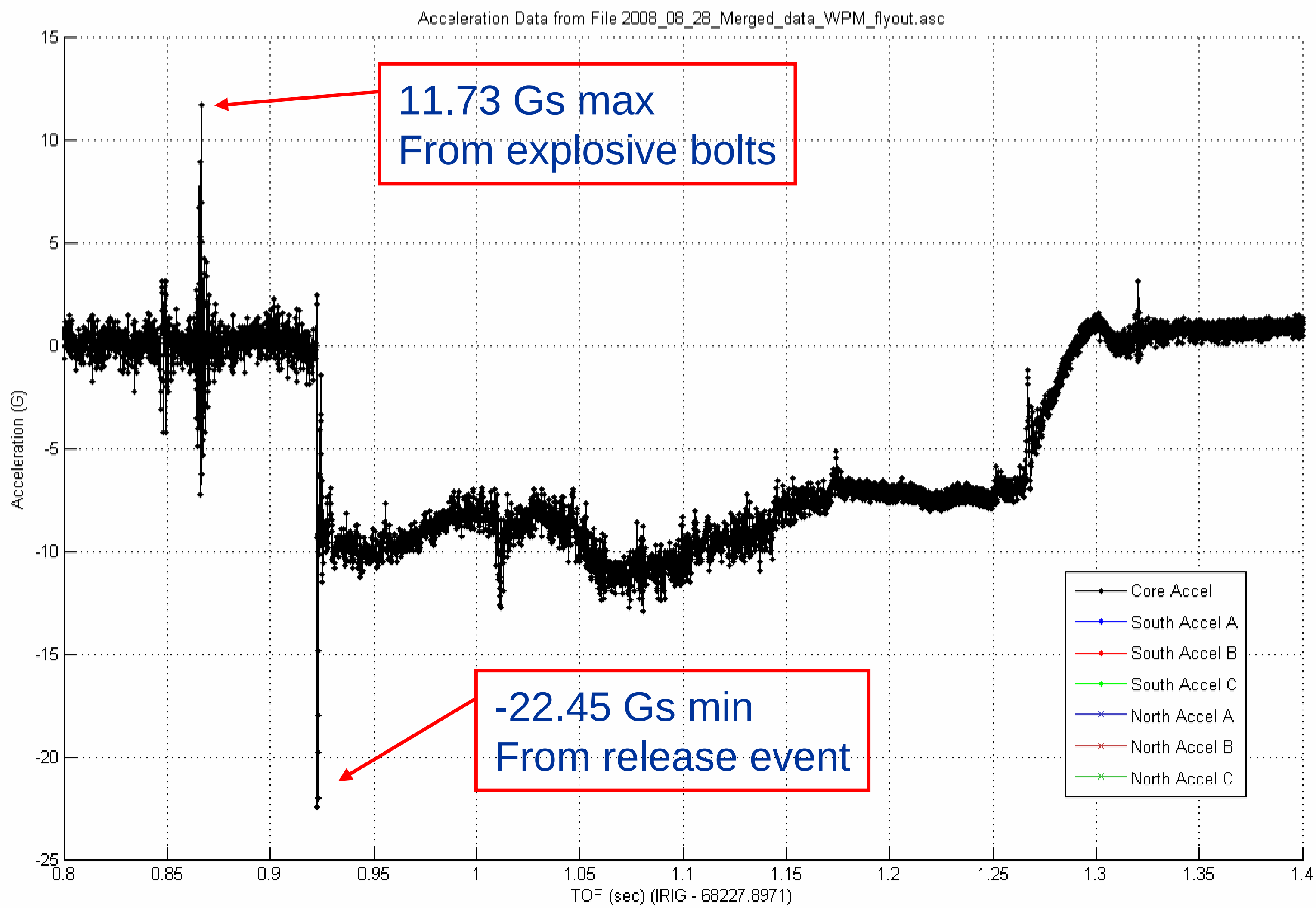
Surface moisture sensor

DISTRIBUTION STATEMENT A

Axial Displacement

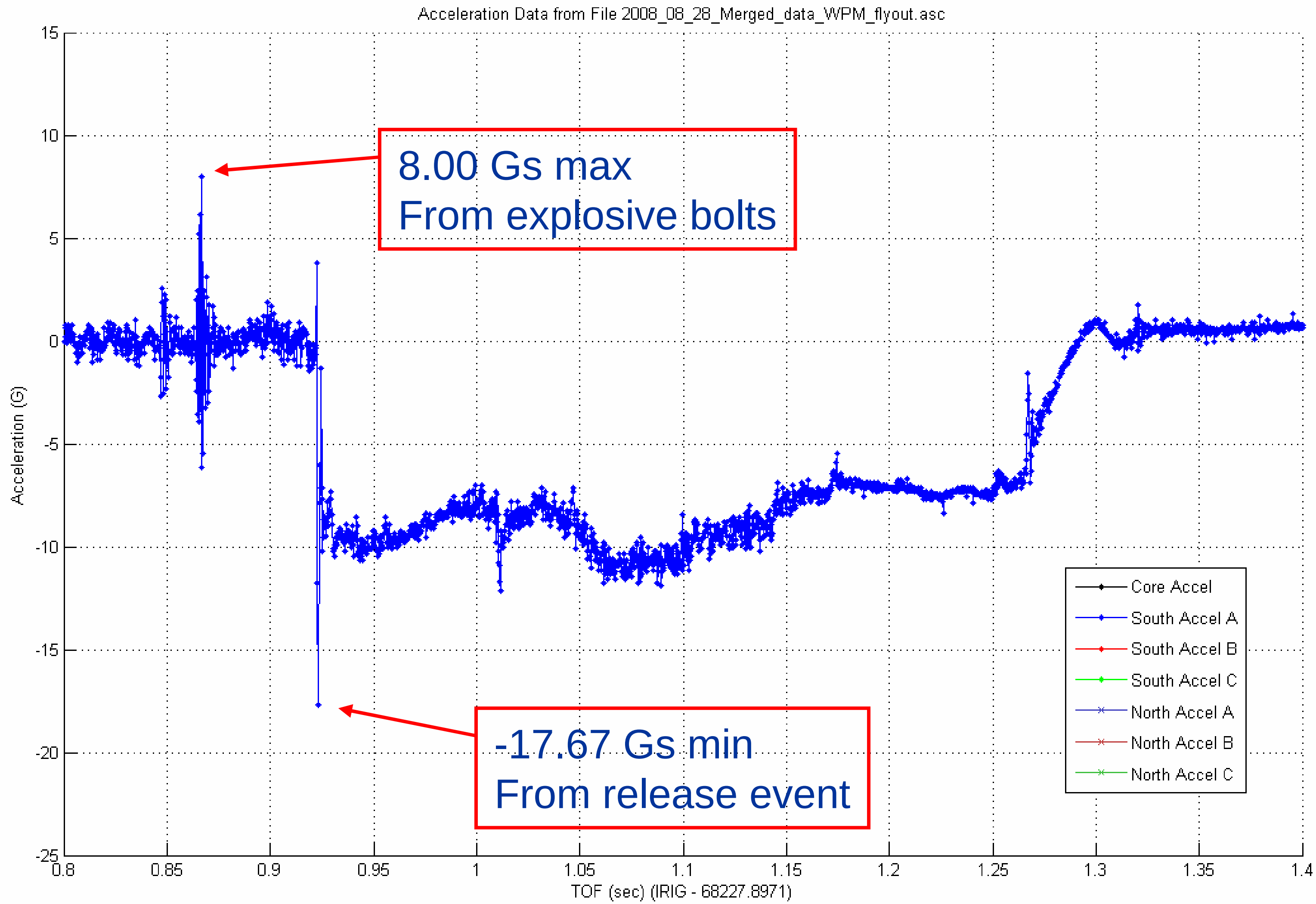


Core (axial) max/min



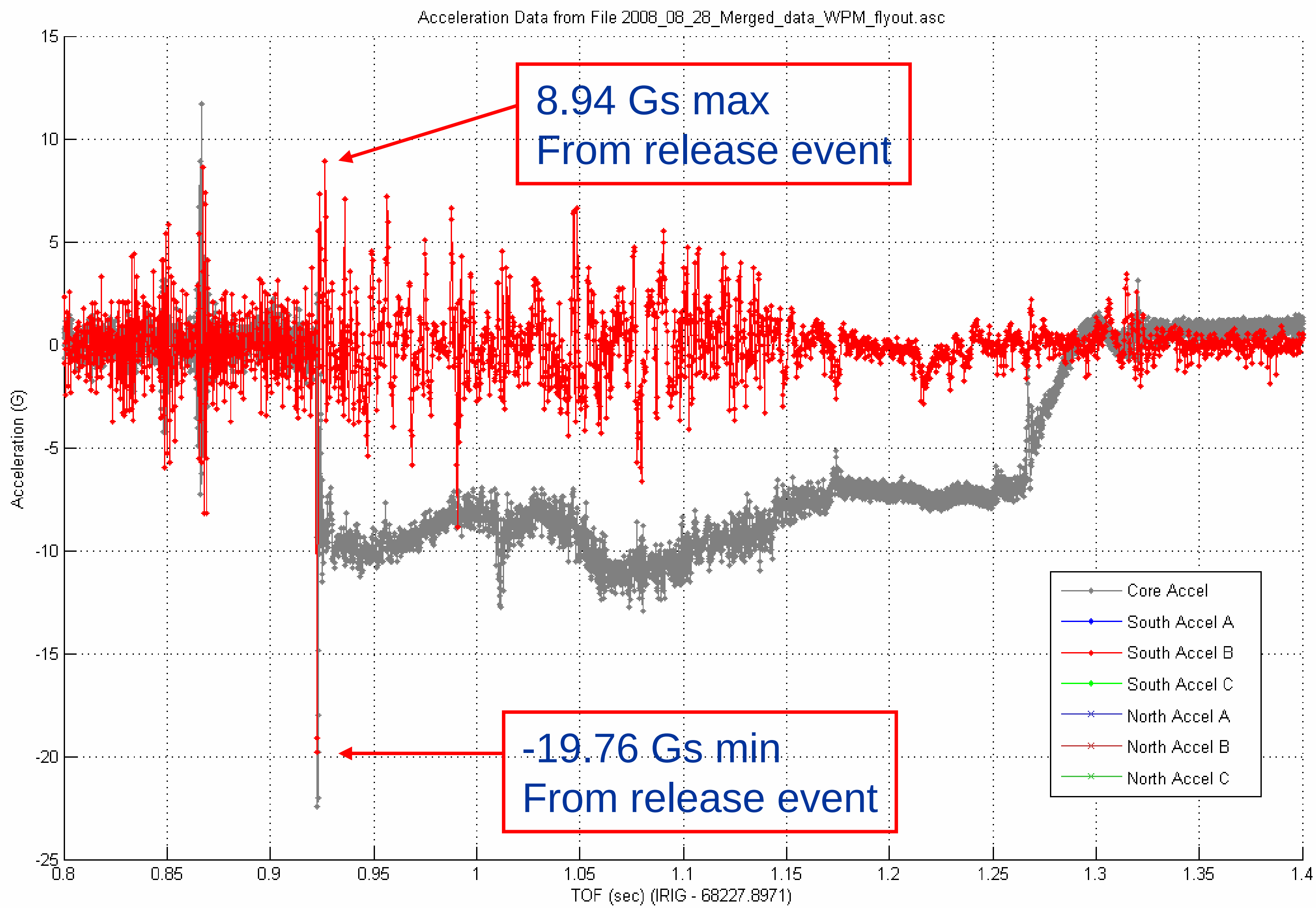
DISTRIBUTION STATEMENT A

ASA (axial) max/min



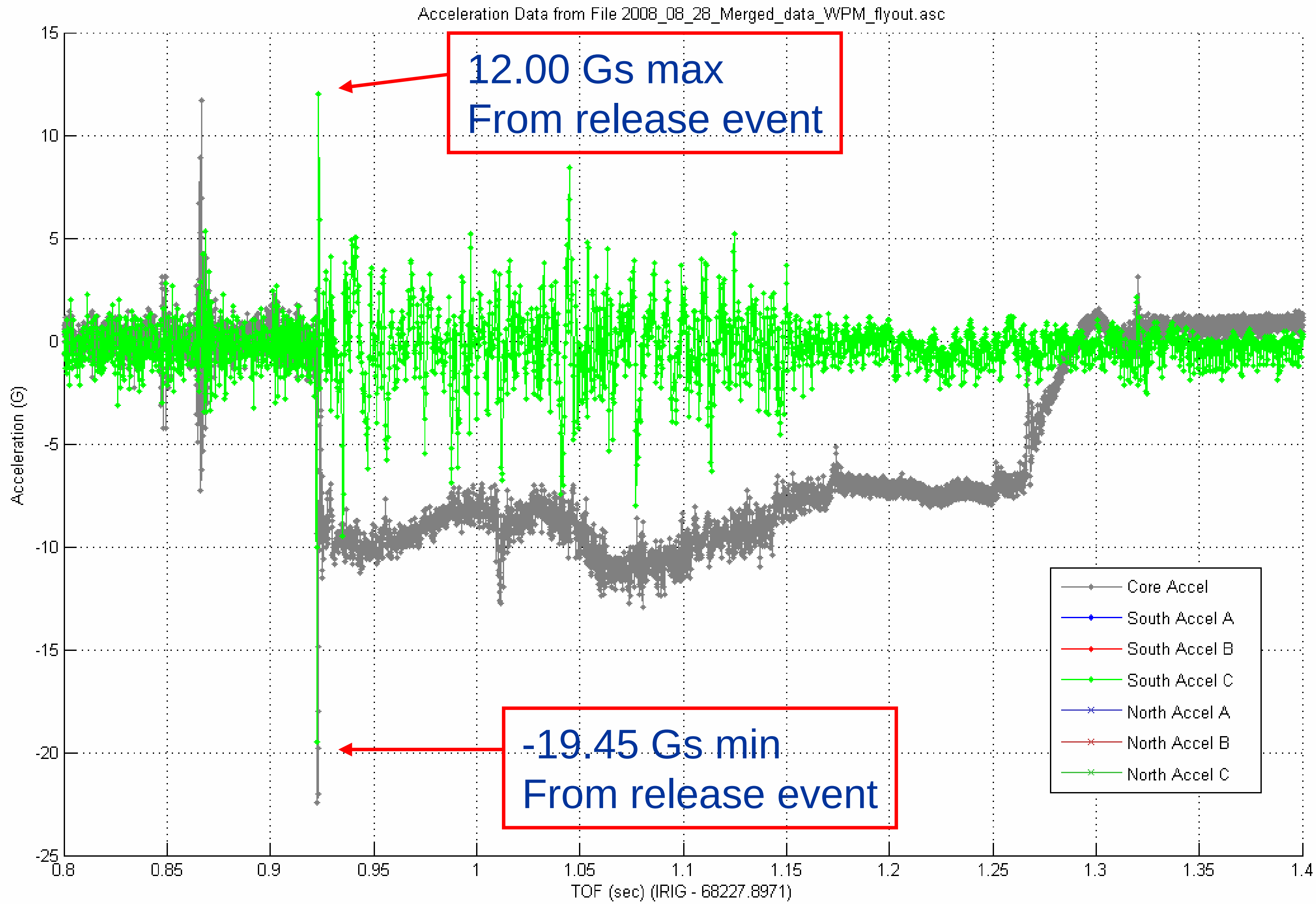
DISTRIBUTION STATEMENT A

ASB (radial) max/min



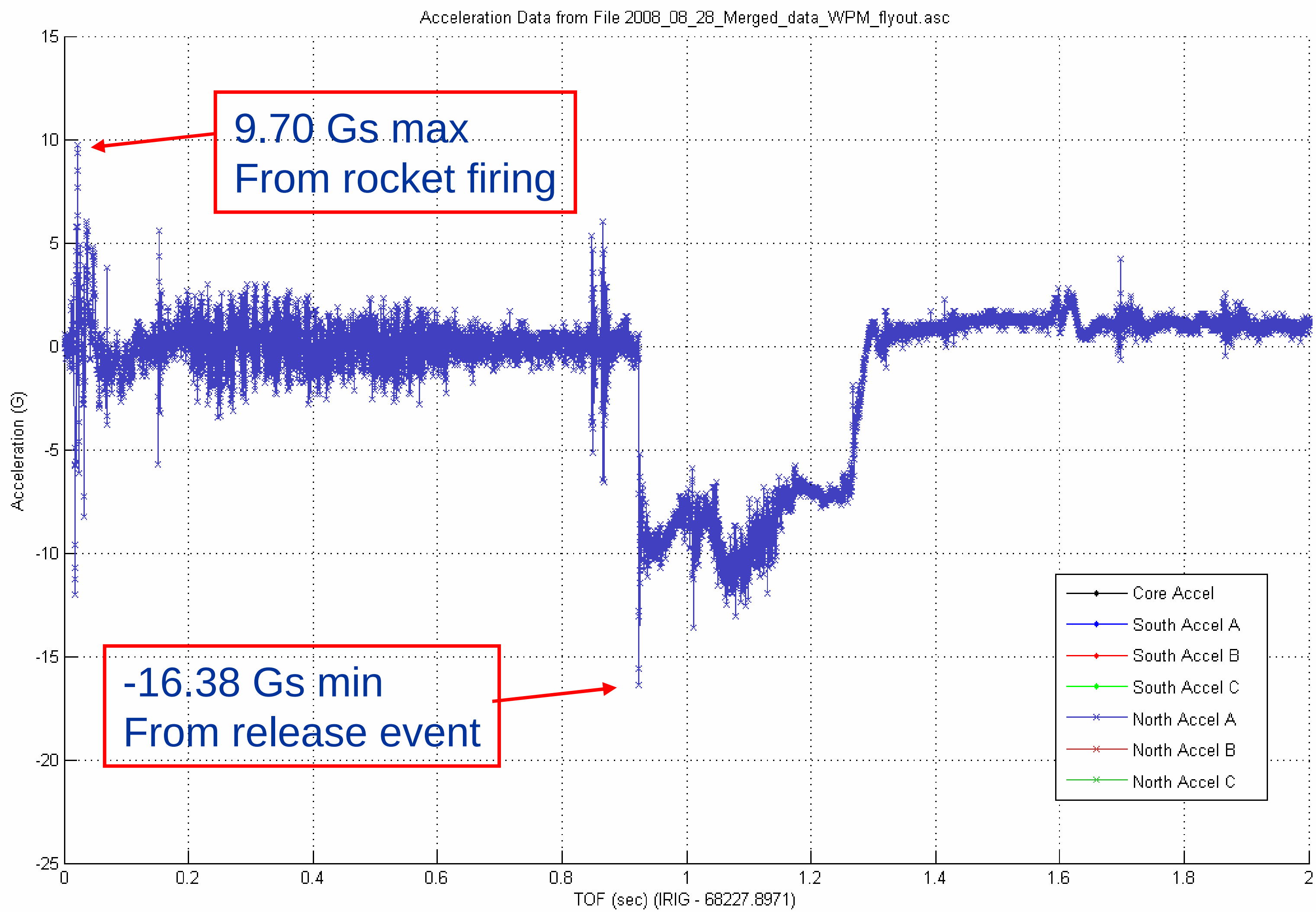
DISTRIBUTION STATEMENT A

ASC (radial) max/min

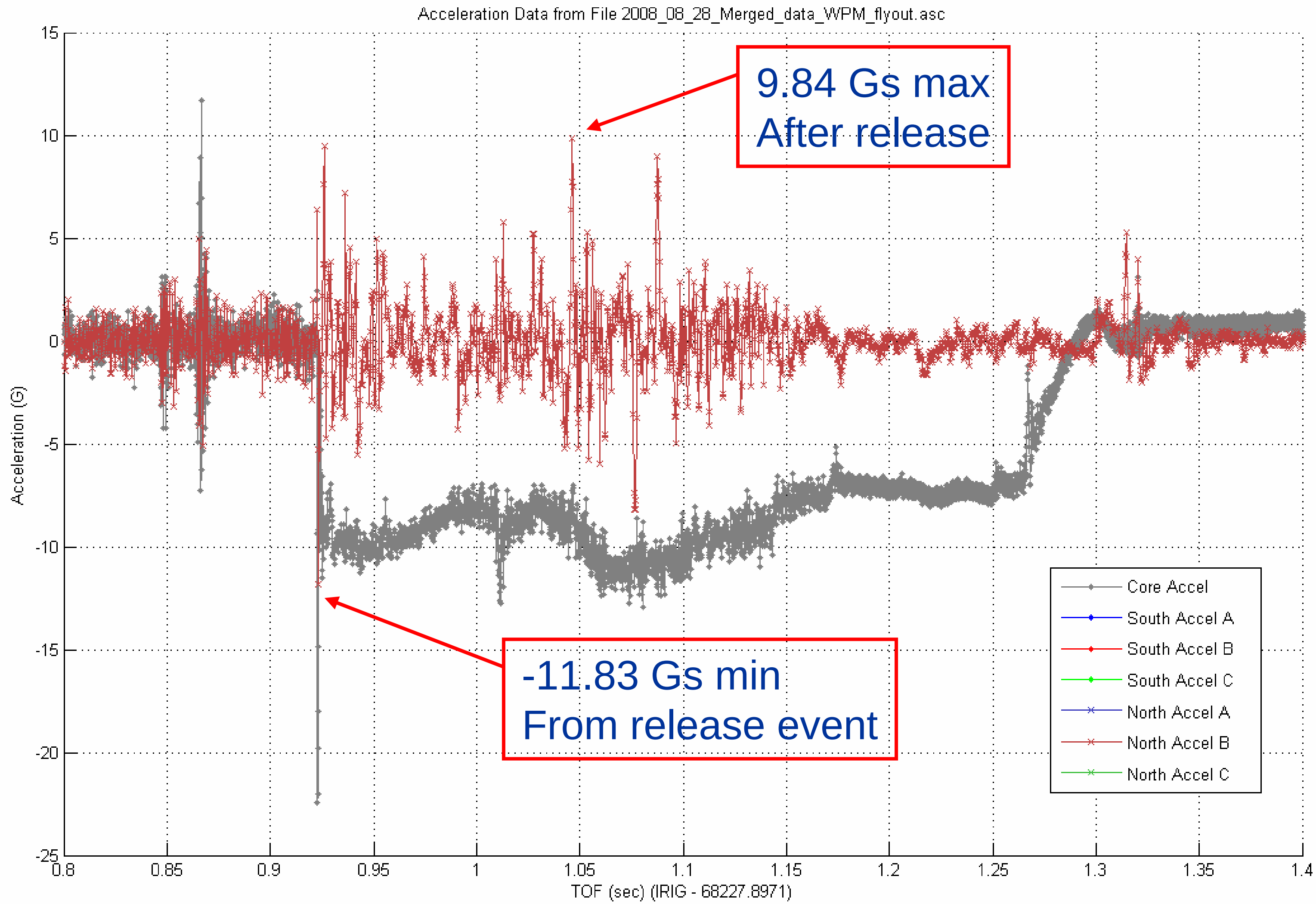


DISTRIBUTION STATEMENT A

ANA (axial) max/min

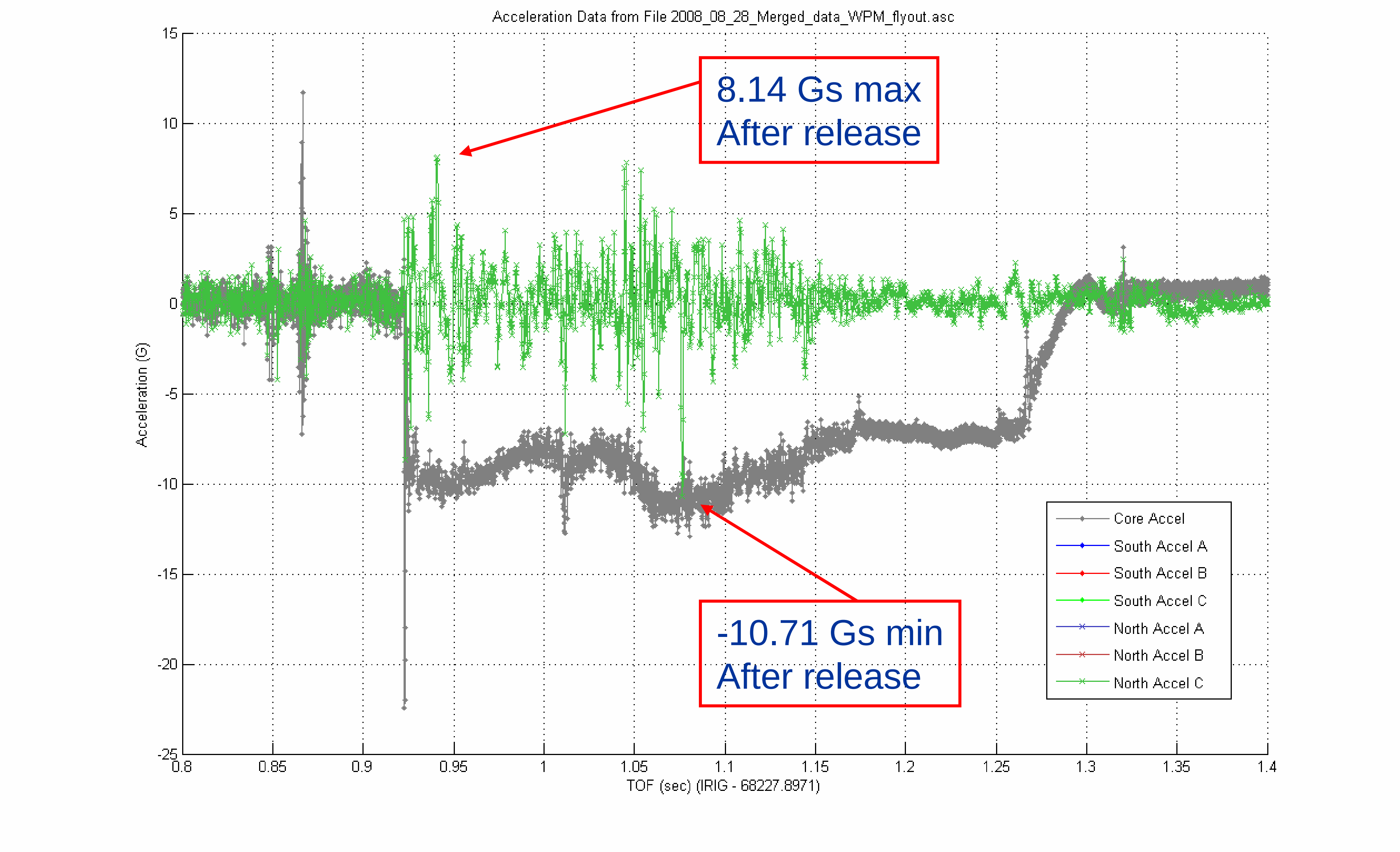


ANB (radial) max/min



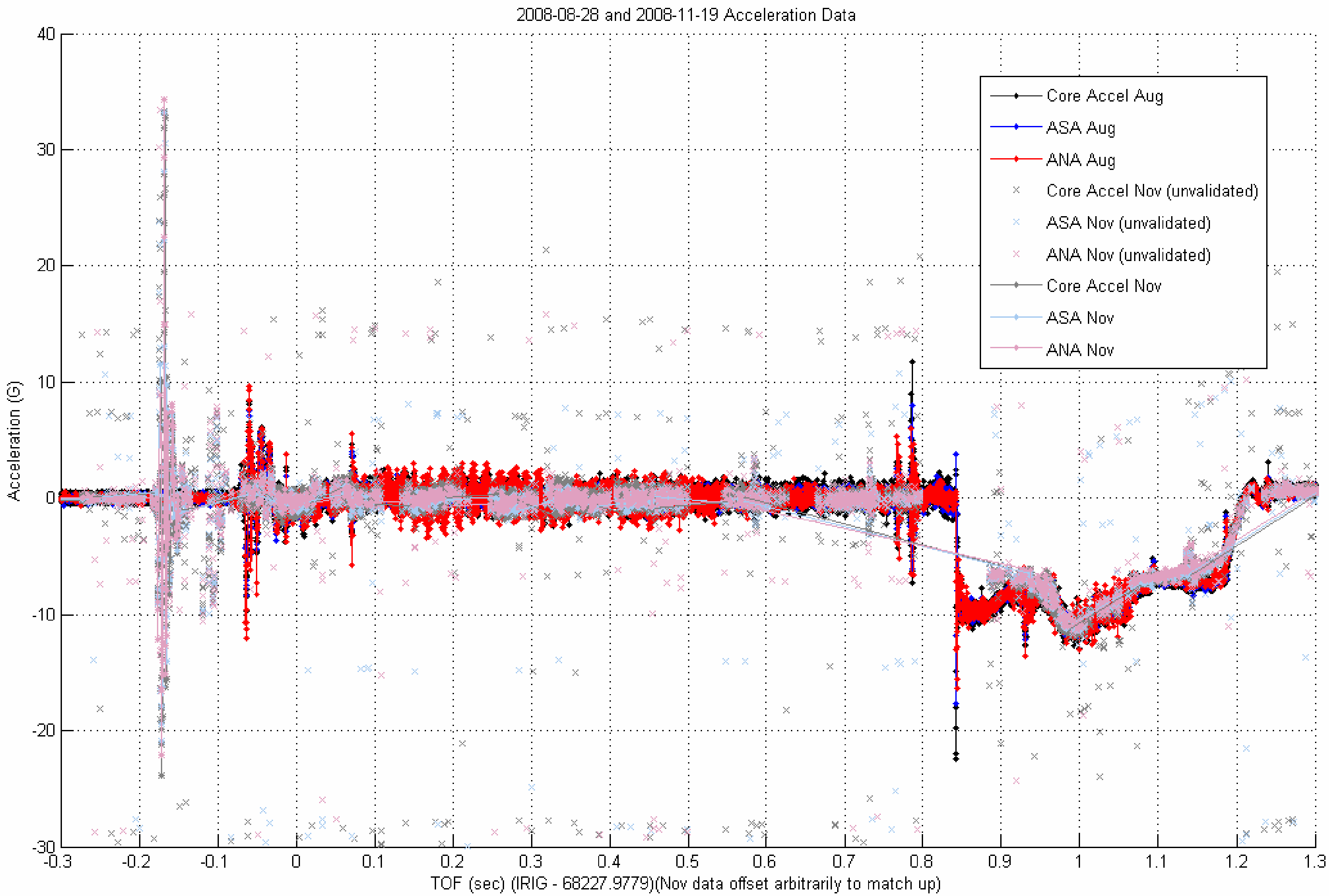
DISTRIBUTION STATEMENT A

ANC (radial) max/min



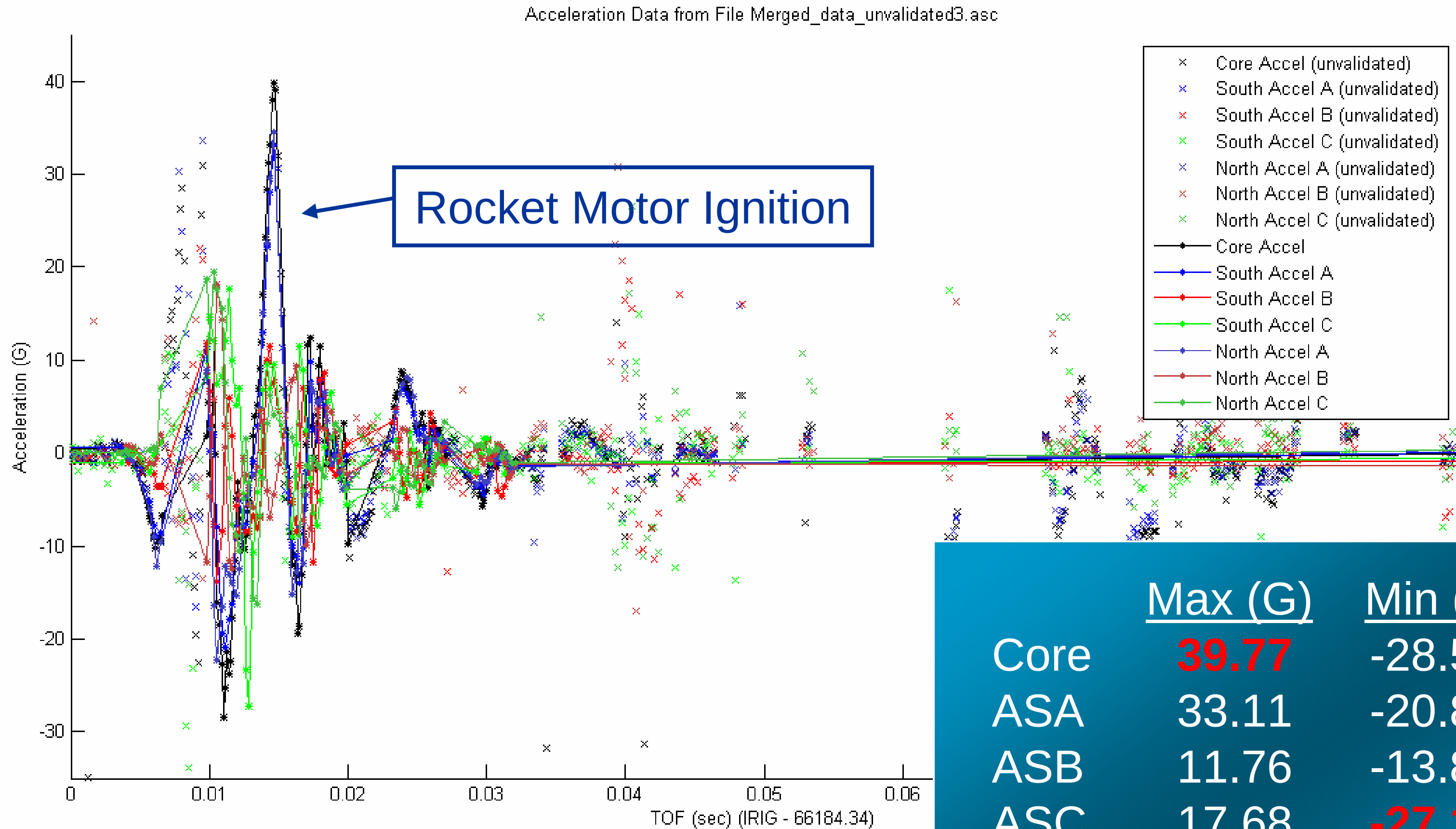
DISTRIBUTION STATEMENT A

Nov 19 2008 Data



DISTRIBUTION STATEMENT A

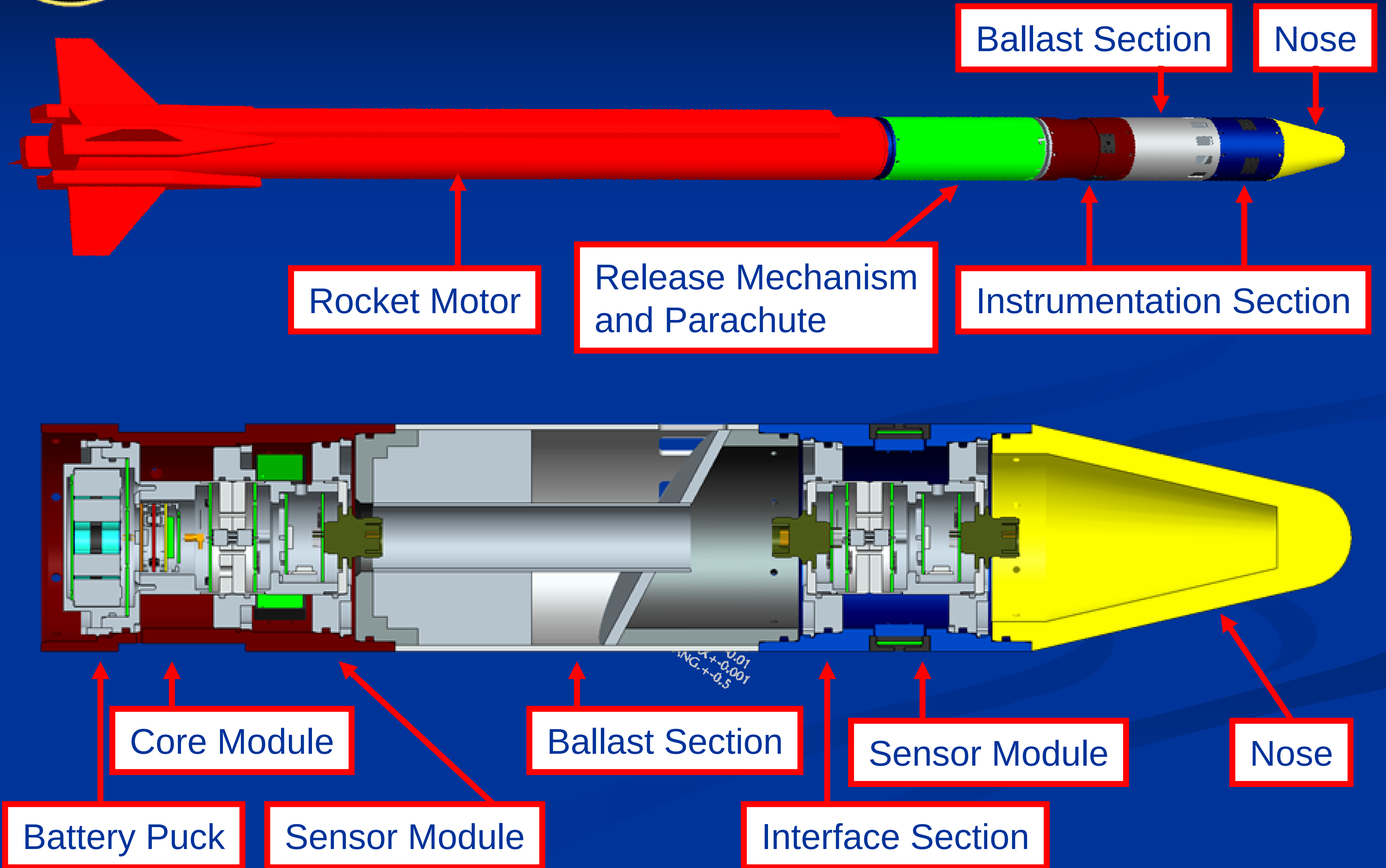
Nov 19 2008 Maxima



	Max (G)	Min (G)
Core	39.77	-28.50
ASA	33.11	-20.84
ASB	11.76	-13.87
ASC	17.68	-27.17
ANA	34.46	-22.22
ANB	18.13	-12.51
ANC	19.42	-16.31

DISTRIBUTION STATEMENT A

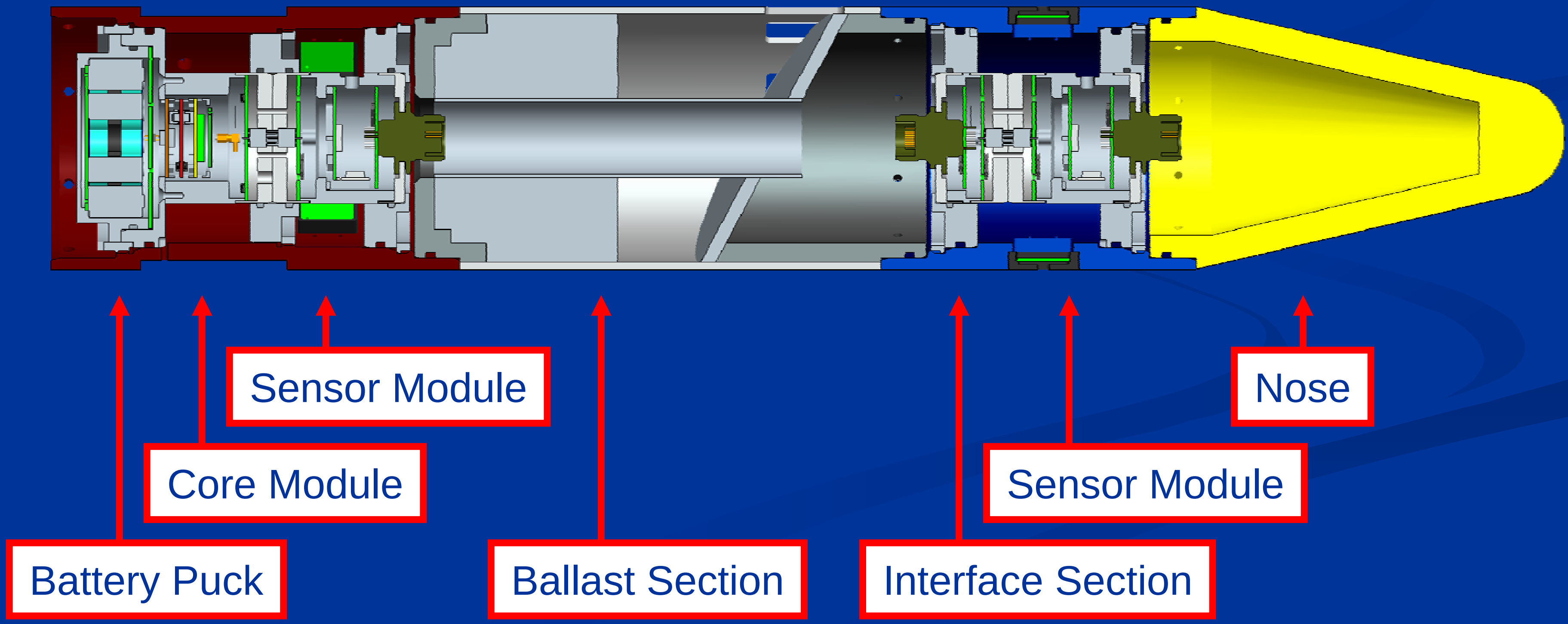
ETF-SWR Overview



DISTRIBUTION STATEMENT A

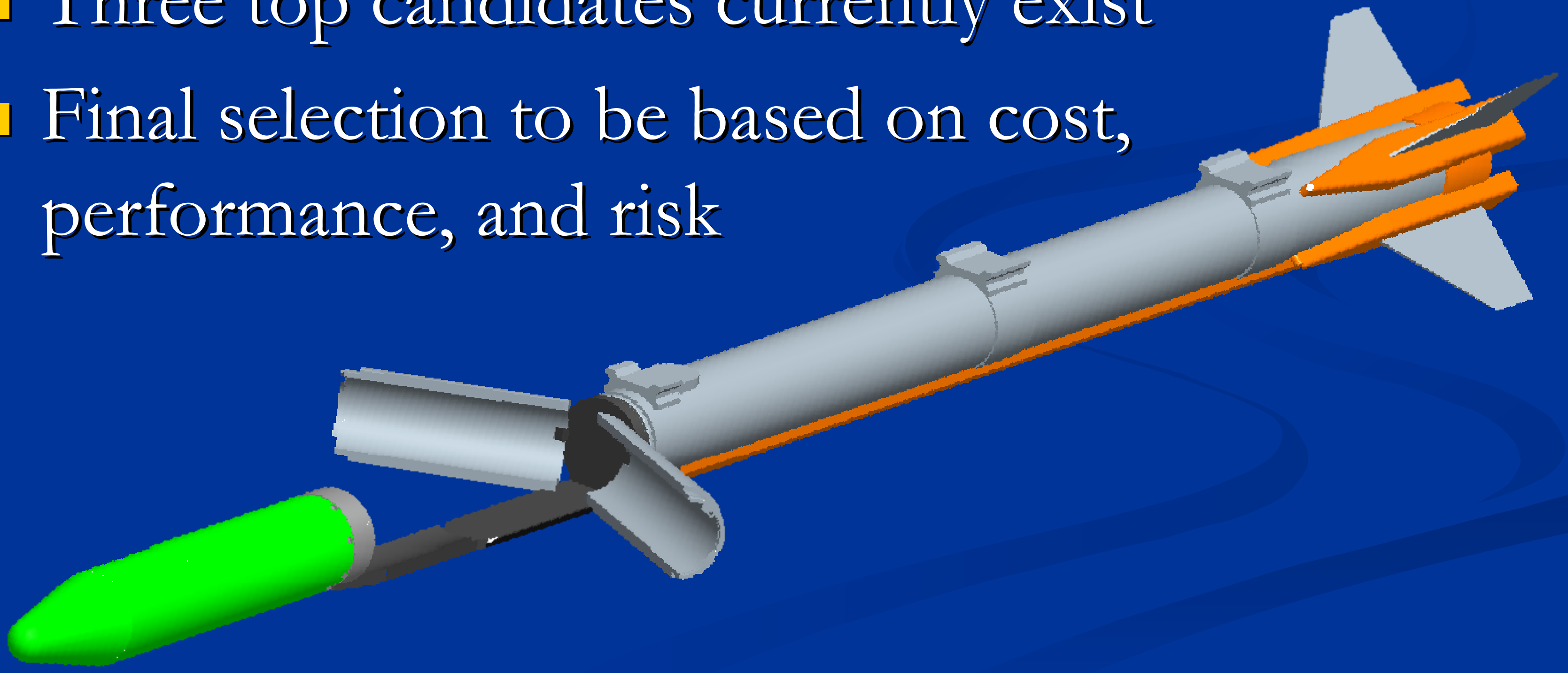
ETF-SWR Instrumentation Section

- Electronic design ported from FY08 JATO work
- Additional sensors (temperature/pressure) to be added into future nose section



Release Mechanisms

- Various release mechanism designs are being explored
- Three top candidates currently exist
- Final selection to be based on cost, performance, and risk



Adaptive Flight Control Surfaces: Revolutionizing Missile & Munition Flight Control Systems

Professor Ron Barrett

Director of the Adaptive Aerostructures Laboratory (AAL)
Aerospace Engineering Department
The University of Kansas, Lawrence, Kansas USA

AAL ...Backroom for the Innovation-Driven Aerospace Organizations of the world...

44th Annual Gun and Missile Systems Conference & Exhibition
Hyatt Regency Crown Center, Kansas City, MO
8 April 2009

Outline:

Purpose:

Describe to the Missile and Munitions Community the revolutionary weapon systems configurations and missions enabled by modern adaptive materials and aerostructures

Outline:

I. Background & Brief Introduction to Adaptive Materials

II. History of Programs

III. New Actuator Class

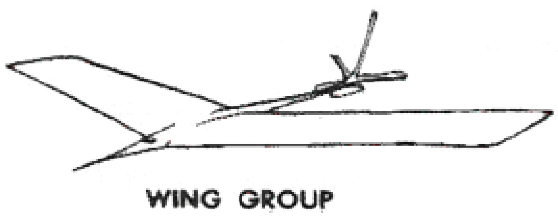
IV. Current & Future Programs Enabled

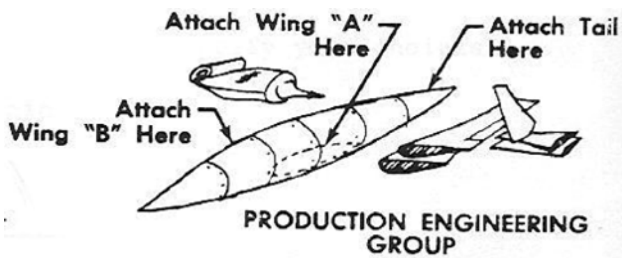
Adaptive Materials

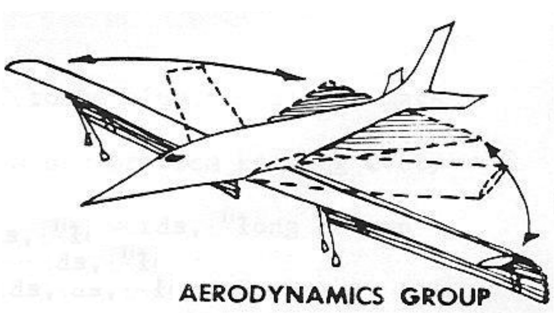
… A Paradigm Shift

Old Paradigm:

Structural deformations indicate that a given loading state is occurring and must therefore be accommodated.





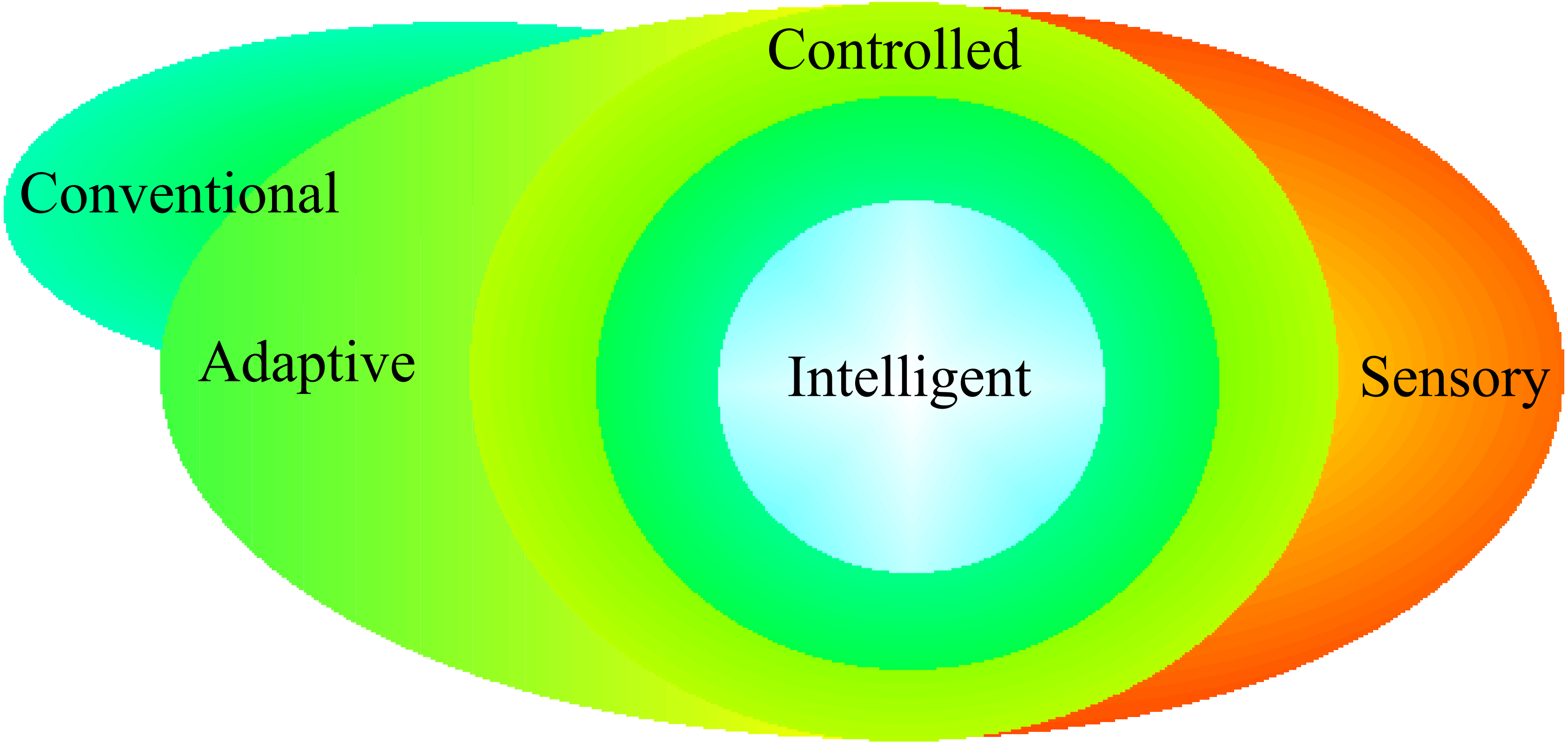


New Paradigm:

Structural deformations can be controlled and can therefore be used to enhance mission effectiveness.

Adaptive Materials:
A (Very) Brief Introduction

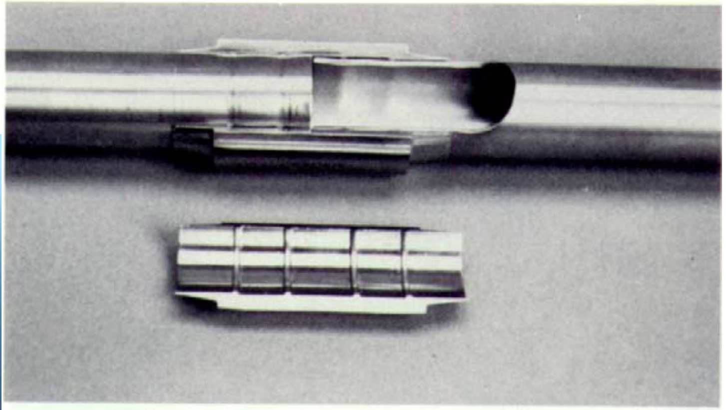
What are Adaptive Materials & Structures?



Adaptive Aerostructures: A (Very) Brief Introduction

- Most Useful Classes of Adaptive Materials:
  - Shape-Memory Alloy - High Deflection, Slow, Lots of Power
  - Variable Rheology Materials - Good for clutching and changing stiffness
  - Piezoceramics - Very Fast, Low Power
  - Optically Adaptive Materials - Newest class, controllable color, luminosity, reflectivity, opacity

Adaptive Materials in Aerospace



Raychem Corporation Cryofit™ SMA Tube Coupler

Grumman F-14 the First aircraft fielded with man-made adaptive materials

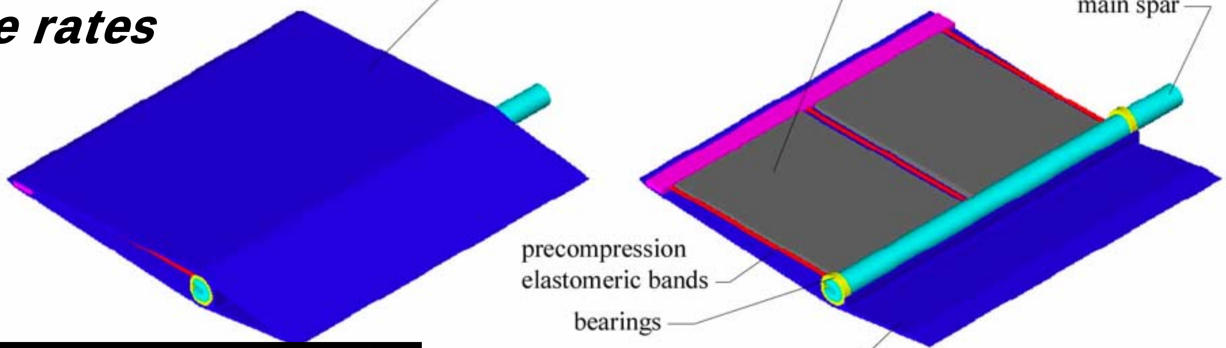
Raychem Corporation Tinel Lock™ SMA Cable Shielding Termination

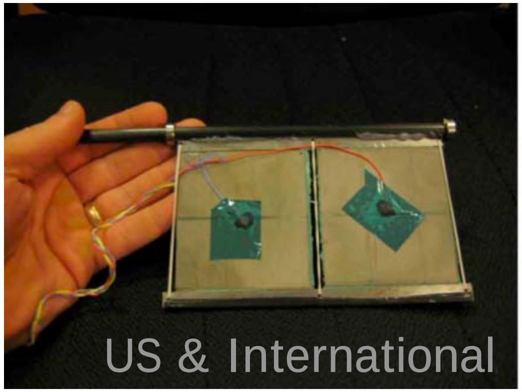
Adaptive Materials in Aerospace

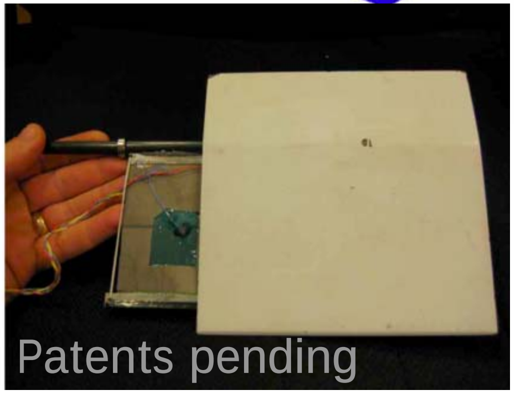
GE90-155B Turbofan on a Boeing 777 Fitted with SMA-Actuated Chevrons

Adaptive Flutter Test Surfaces

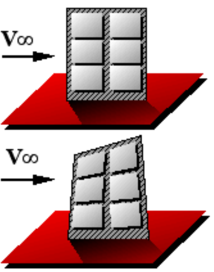
- ***Solid State***
- ***Order of magnitude less device weight***
- ***Order of magnitude less installation weight***
- ***Half the acquisition price of the conventional system***
- ***Half the installation price and downtime of the conventional system***
- ***Exacting Phase Control***
- ***Flight Rated to Mach 3***
- ***Half the flutter insurance rates***



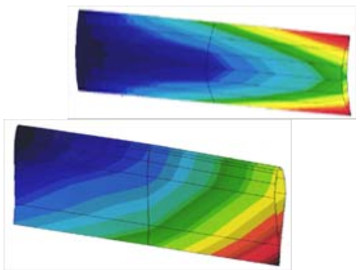


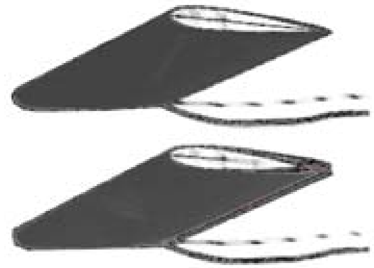


Early Adaptive Aerostructures



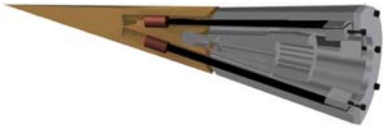
Twist & camber-active subsonic & supersonic wings





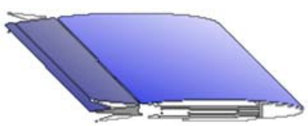
1st Pitch-Active Missile Fins

1st Adaptive Gun-Launched Munitions

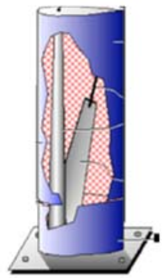


1st Adaptive Gravity Weapons

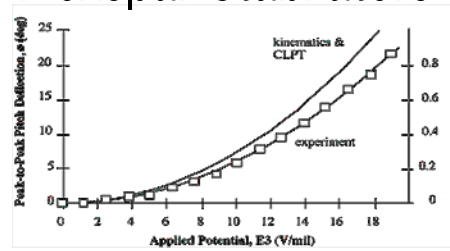
1985 1990 1995



Twist-active plates & flaps

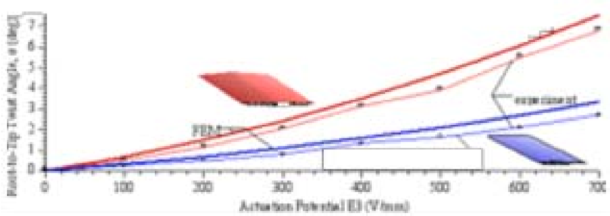


Flexspar Stabilators



Crawley, Andersen, Spangler, Hall, Lazarus (MIT)

Good theory-experiment correlation



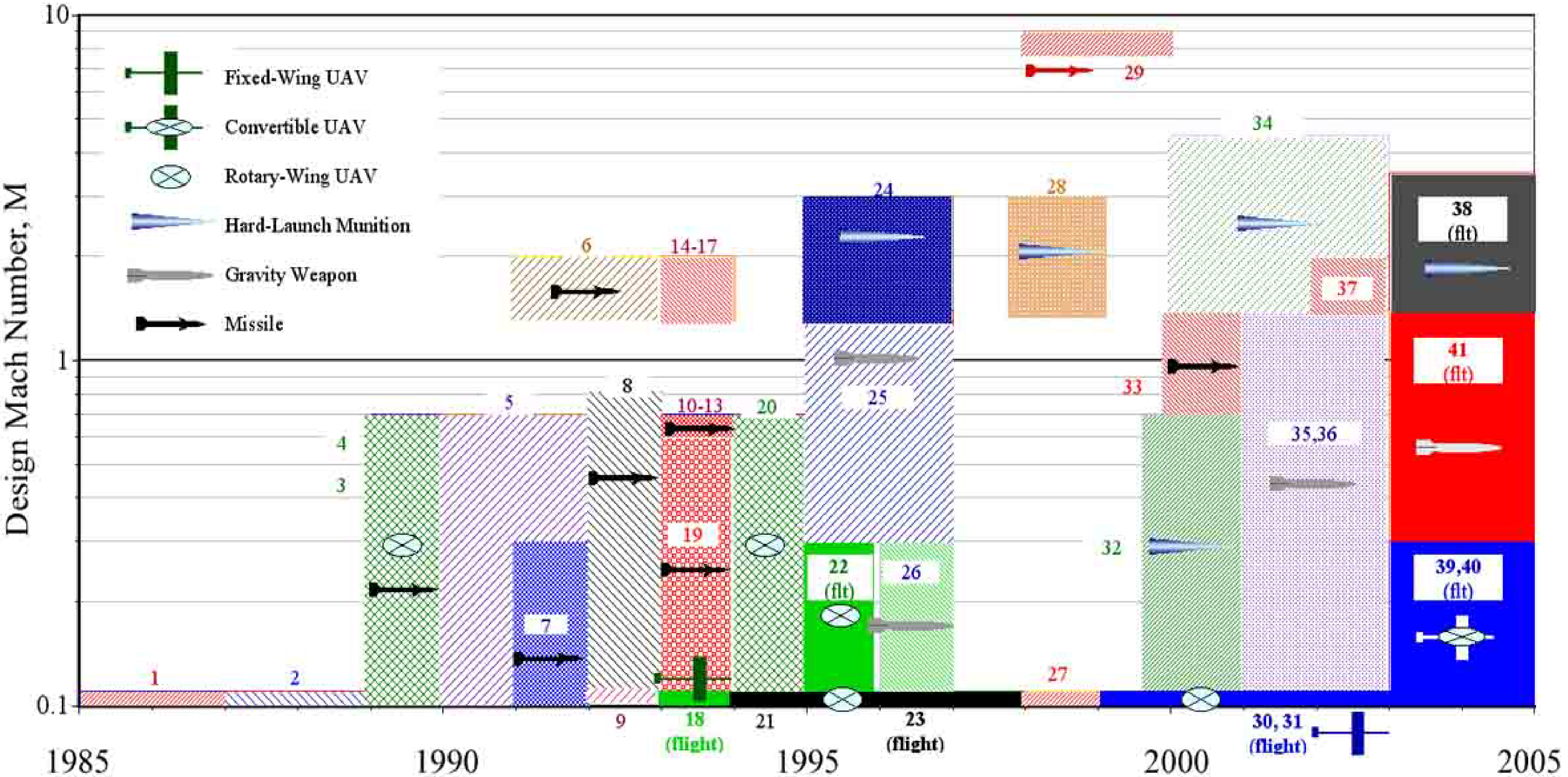
1st Flying Adaptive UAV

First 20 years of Programs with Lineage to Flying Adaptive UAVs

		Project	Modeling Technique		Test Techniques			Sponsor
			Closed or CLPT	FEM	Bench	Stand or Tunnel	Flight	
21	'94-95	Aeroservoelastic Flexspar Fin	3	3	3	3		AAL
22	**'95-96**	**Solid State Adaptive Hiller Servopaddle Rotor (Gamara)**	**3**		**3**	**3**	**3**	**NSF**
23	**'94-97**	**Flexspar Micro Aerial Vehicle Stabilator (Kolibri)**	**3**		**3**	**3**	**3**	**DoD CDTO**
24	'95-97	Barrel-Launched Adaptive Munition (BLAM)	3		3	3		AFOSR
25	'95-97	Smart Compressed Reversed Adaptive Munition (SCRAM)	3		3	3		WL/MNAV
26	'95-97	Monolithic Rotationally Active Linear Actuator (RALA)	3		3	3		WL/MNAV/Boein
27	'97-98	Pitch-Active Torque-Plate Wing	3		3	3		AAL
28	'98-99	Range-Extended Adaptive Munition (REAM)	3		3	3		DARPA
29	'98-00	Hypersonic Interceptor Test Technology (HITT)	3		3	3		SMDC/Schafer
30	**'98-00**	**Coleopter MAV Flexspar Stabilators**	**3**		**3**	**3**	**3**	**DARPA**
31	**'00-01**	**Pitch-Active SMA Wing**	**3**		**3**		**3**	**AAL**
32	'00-01	Light Fighter Lethality Fin MicroFlex Actuator	3		3	3		TACOM/ARDEC
33	'01-02	Pitch-Active Curvilinear Fin Actuator	3		3	3		AMCOM
34	'01-03	Shipborne C'measure Range-Ex. Adaptive Munition (	3		3	3		TACOM/ARDEC
35	'00-03	Thunder Multilaminate RALA Fin	3		3			WL/MNAV
36	'00-03	Centerline Precompression Multilaminate RALA Fin	3		3			WL/MNAV
37	'02-03	Center Pivot Flexspar Fin	3					ARL
38	**2003-**	**StAB**	**3**	**3**	**3**	**3**	**3**	**TUD/TNO**
39	**2003-**	**Coleopter PBP Grid Fin**	**3**	**3**	**3**	**3**	**3**	**TUD**
40	**2003-**	**Coleopter PBP Turning Vane Flap**	**3**	**3**	**3**	**3**	**3**	**TUD**
41	**2003-**	**Twist-Active Wings for Extended-Range Gravity W**	**3**	**3**	**3**	**3**	**3**	**WL/MNAV/Boein**

R. M. Ba

Overview of Programs with Lineage to Flying Adaptive UAVs



R. M. Ba

Brief Guided Round History

M712 Copperhead 1975

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
decompressor
are needed to see this picture.

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

XM 982 Excalibur & ERGM

Guided Round History

Reducing the caliber…

M 247 Sergeant York 1977 - 1985

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

Guided Round History

How to guide subscale rounds?

What is needed in such a flight control actuator???

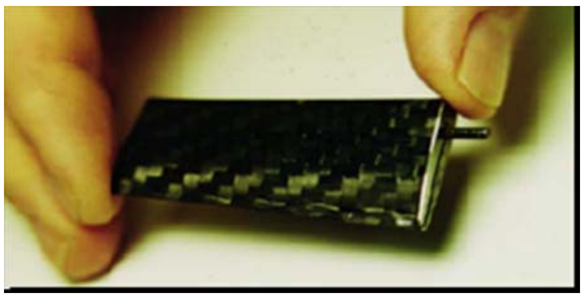
- Setback tolerance: 30,000 - 100,000g's
- Balloting, setforward, ringing impervious
- Compatible with supersonic control effectors
- Not affected by atmospherics (rain, dust, dirt, snow, etc.)
- High feedback command fidelity maintained during all flight phases
- 20 yr storage life
- -40 to +145°F
- Lightweight (<1g), Low Volume (<1cc), Low Power (10's of mW)
- High bandwidth (>200 Hz)
- Production shipset costs in single dollars... at most

One possible solution... from the MAV world

The 1st Micro Aerial Vehicle (MAV) -- by the DoD CounterDrug Technology Office 1994 - '98

QuickTime™ and a H.264 decompressor are needed to see this picture.

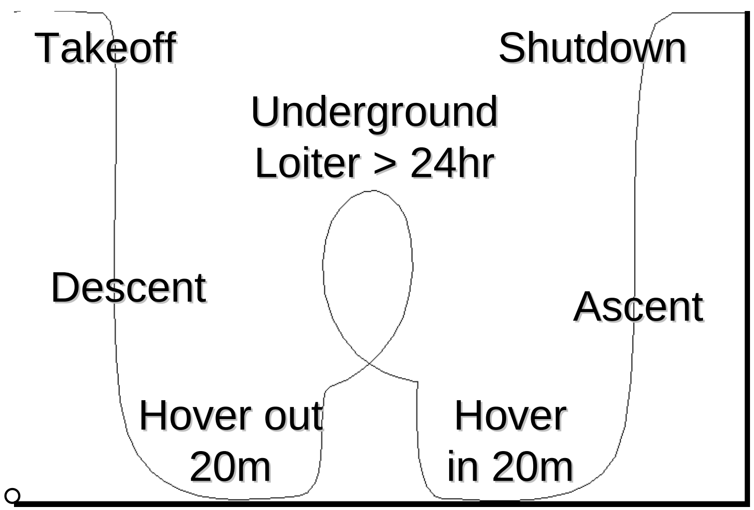
Enabled by Flexspar Piezoceramic Stabilators

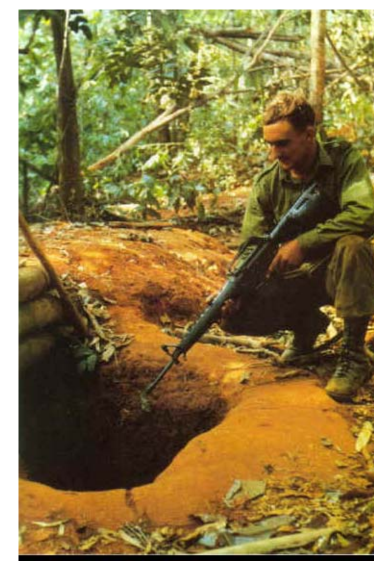


Stabilator Characteristics:

- total mass 5.2g
- actuator mass: 380 mg
- max. static deflections: ±11°
- max power consumption: 14 mW
- pitch corner frequency: 47 Hz
- first natural frequency in pitch: 23 Hz

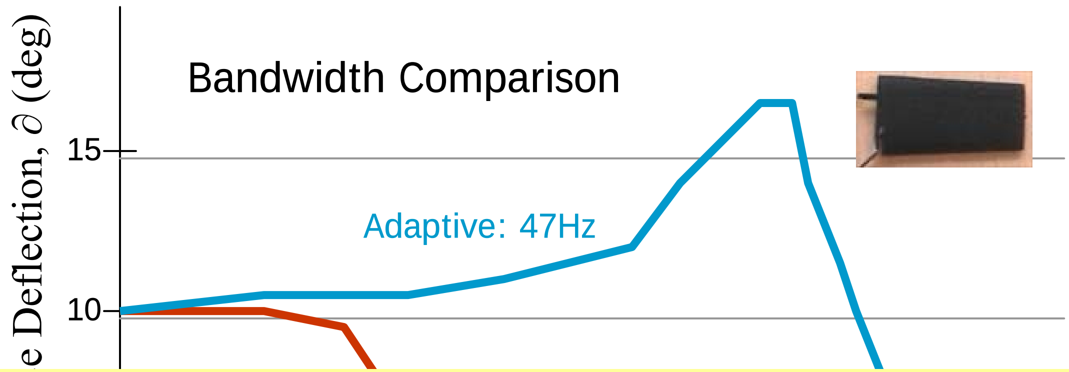
Mission Profile:





Advanced UAVs:

Driving the need for Adaptive Actuators -- faster, lighter, stronger



Adaptive Surfaces vs. Conventional Servos

- 96% reduction in power consumption
- 16x increase in bandwidth
- 99.2% decrease in slop
- 12% OWE savings
- 8% MGWTO savings

Operating Empty Weight Fraction

Guiding Lower Caliber Rounds… More History

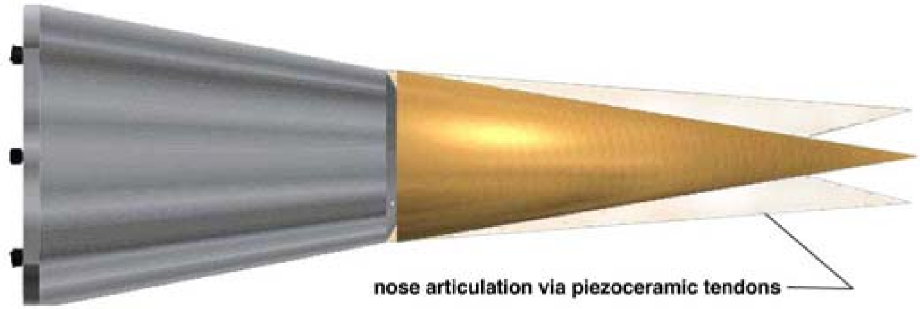
Barrel-Launched Adaptive Munition (BLAM) Program 1995 - '97

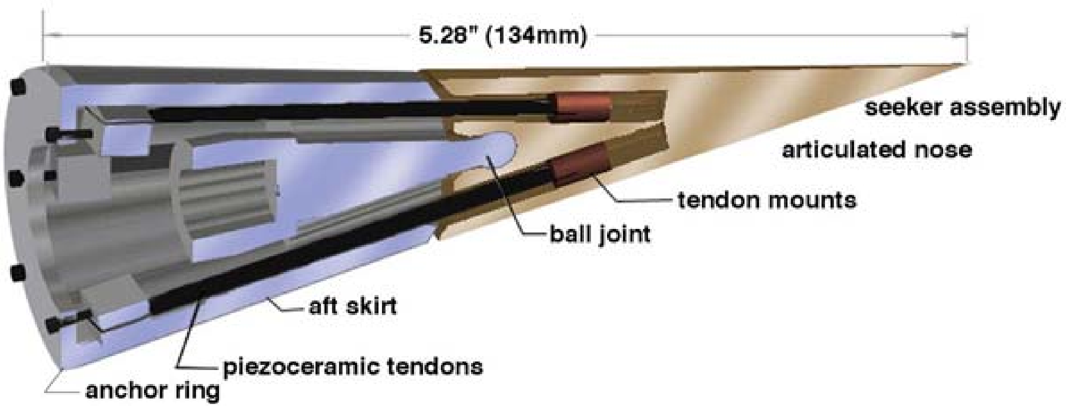
USAF/AFRL-MNAV

- Aerial Gunnery (20 - 105mm)
- Extend Range
- 2g maneuver

  (Eglin AFB tests '97)

  (Mach 3.3 tests '96-'97)
- Increase hit probability
- Increase probability of a kill given a hit
- Reduce total gun system weight fraction



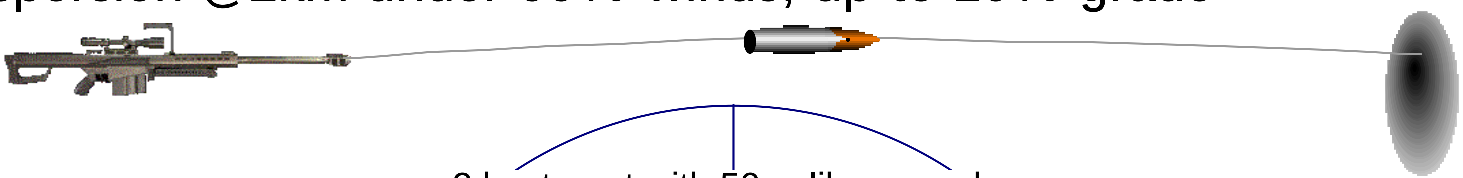


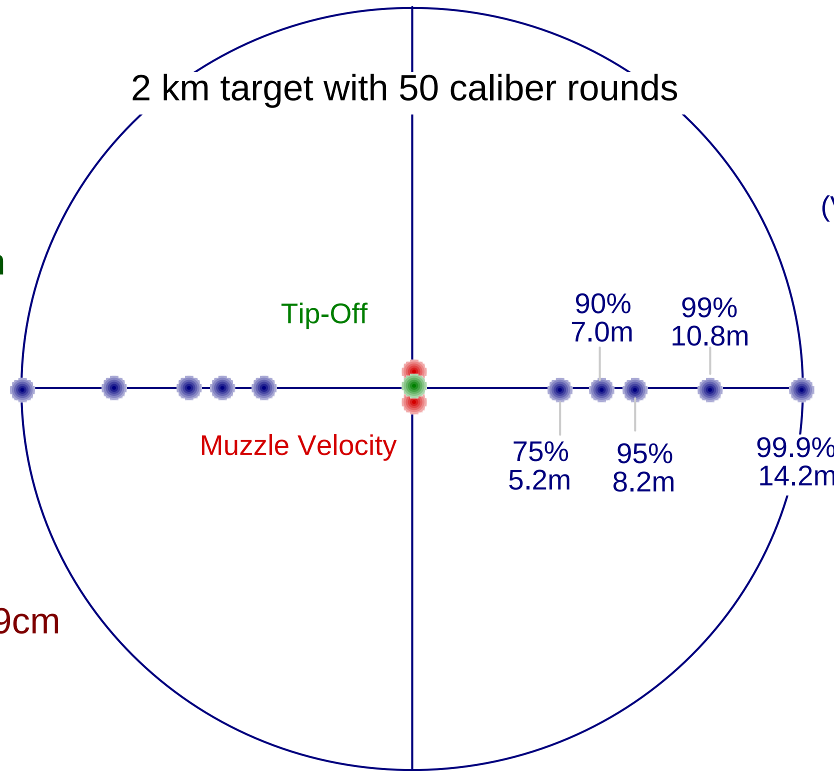
Guiding Small Arms Rounds… More History

Range-Extended Adaptive Munition (REAM) Program 1998 - '99

TACOM-ARDEC (Picatinny-APG) Phase I SBIR

- Guide 50 cal sniper rounds against targets moving up to 100km/hr
- 10cm dispersion @2km under 99% winds, up to 10% grade





Tip-Off Rate:
4 rad/s error ~ 25cm
12 rad/s error ~ 75cm

Crosswinds
(Von Kárman Spectrum)

V ~ $\chi^2(\nu)$
Vav = 4.03 kts
75th%: 5.21 kts
90th%: 6.95 kts
95th%: 8.15 kts
99th%: 10.7 kts
99.9%: 14.2 kts

Muzzle Velocity
1% change error ~ 99cm

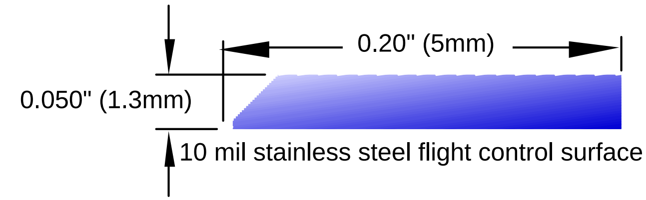
Guiding Small Arms Rounds... More History

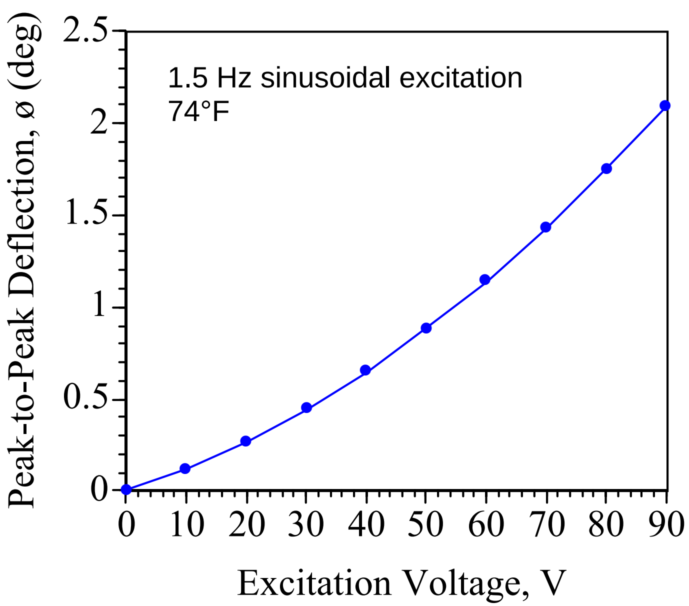
Range-Extended Adaptive Munition (REAM) IRAD 1999 - 2001

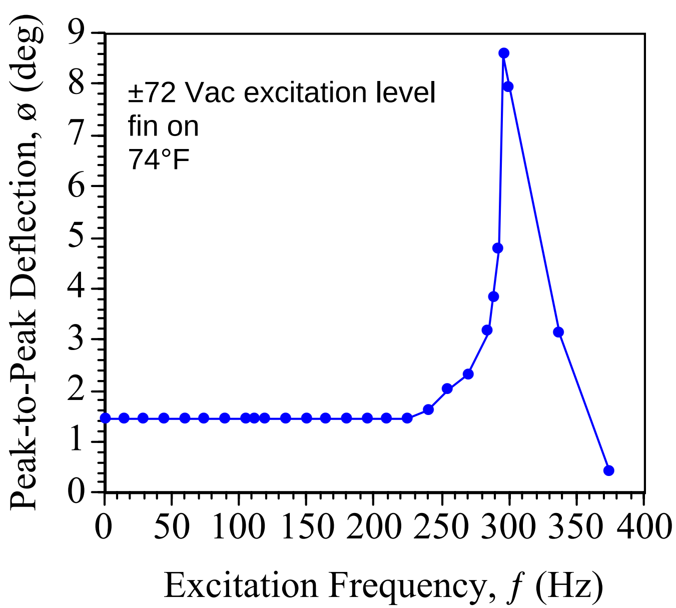
BAT-Lutronix Corp. developed supersonic piezoelectric FCS actuators

Flight Control Surface and Actuator Performance

Max Power Consumption: 28 mW
Nominal Power Consumption: 3.5 mW
Static Power Consumption: < 1µW
Design Mach Range: 0.8 - 4.5, STP
Design Accelerations: 25k g's







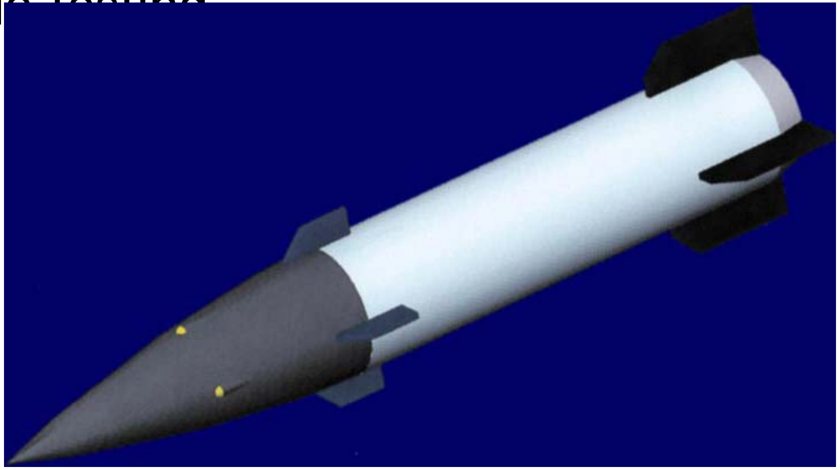
Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II

- Change from sniping to countering high jinking rate sea-skimming missiles
- Change from 0.50 caliber to 40mm
- Change from ~2g's of maneuver authority to many tens of g's
- Entire FCS passed 41,000g shock table testing

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.



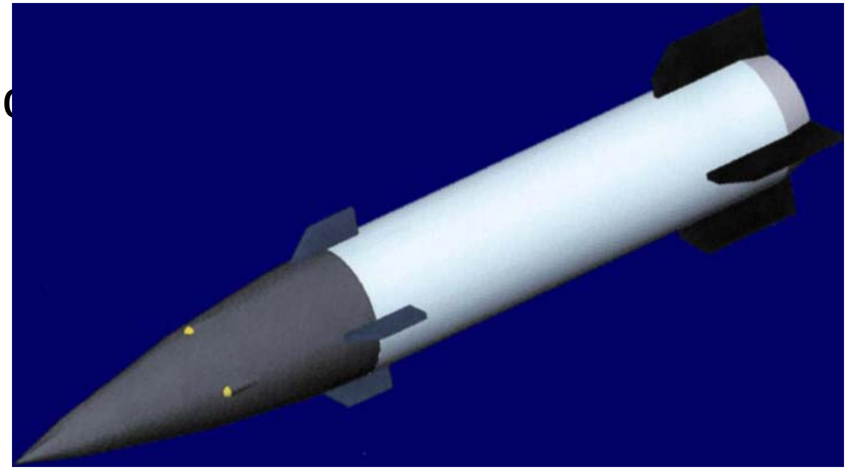
Guiding Small Arms Rounds… More History

Shipborne Countermeasure Range-Extended Adaptive Munition (SCREAM) Program 2001 - '03

DARPA-TACOM ARDEC SBIR Phase II

SCREAM Actuator Challenges:

- Long actuator bay length
- Difficulty pushing beyond 50,000g's
- Low deflection -- ~ok for sniper, not c



Now Where???

Guiding Small Arms Rounds… The Ephphany!

Discoveries from Europe… 2003 - 2004

PBP Actuators: Real Performance!

- **Fraction of the weight, size & power consumption of US Actuators (i.e. much smaller actuator bays)**
- **200+% deflection increases**
- **Higher bandwidth**
- **Lower cost**
- **Lower g-sensitivity**

FIG. 10

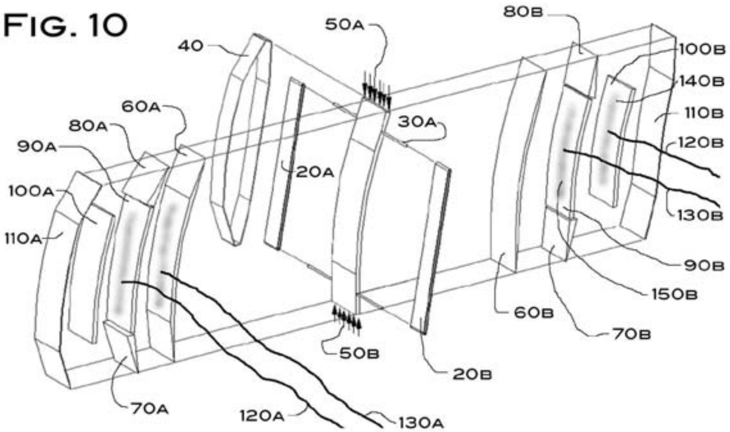
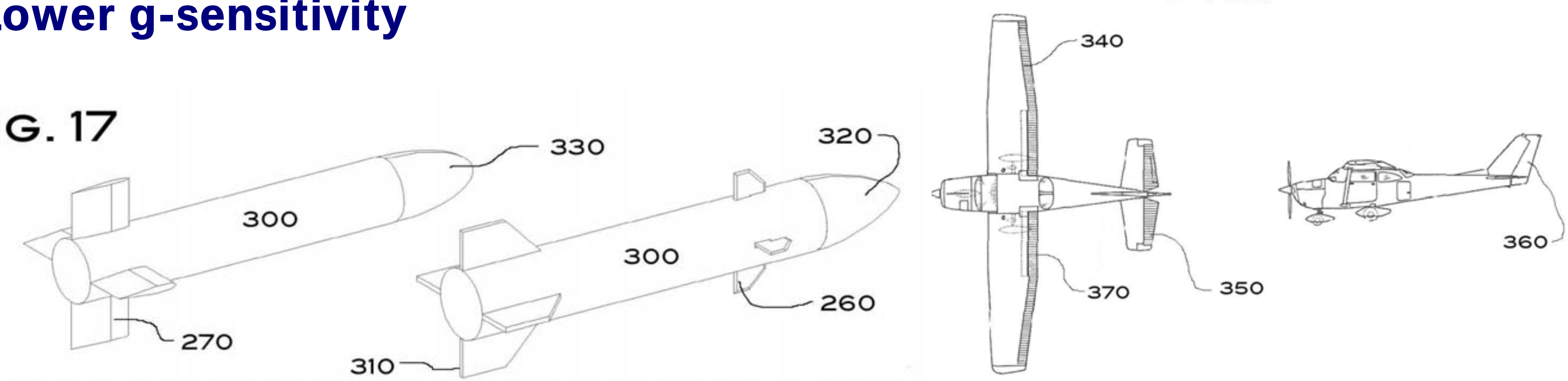


FIG. 17

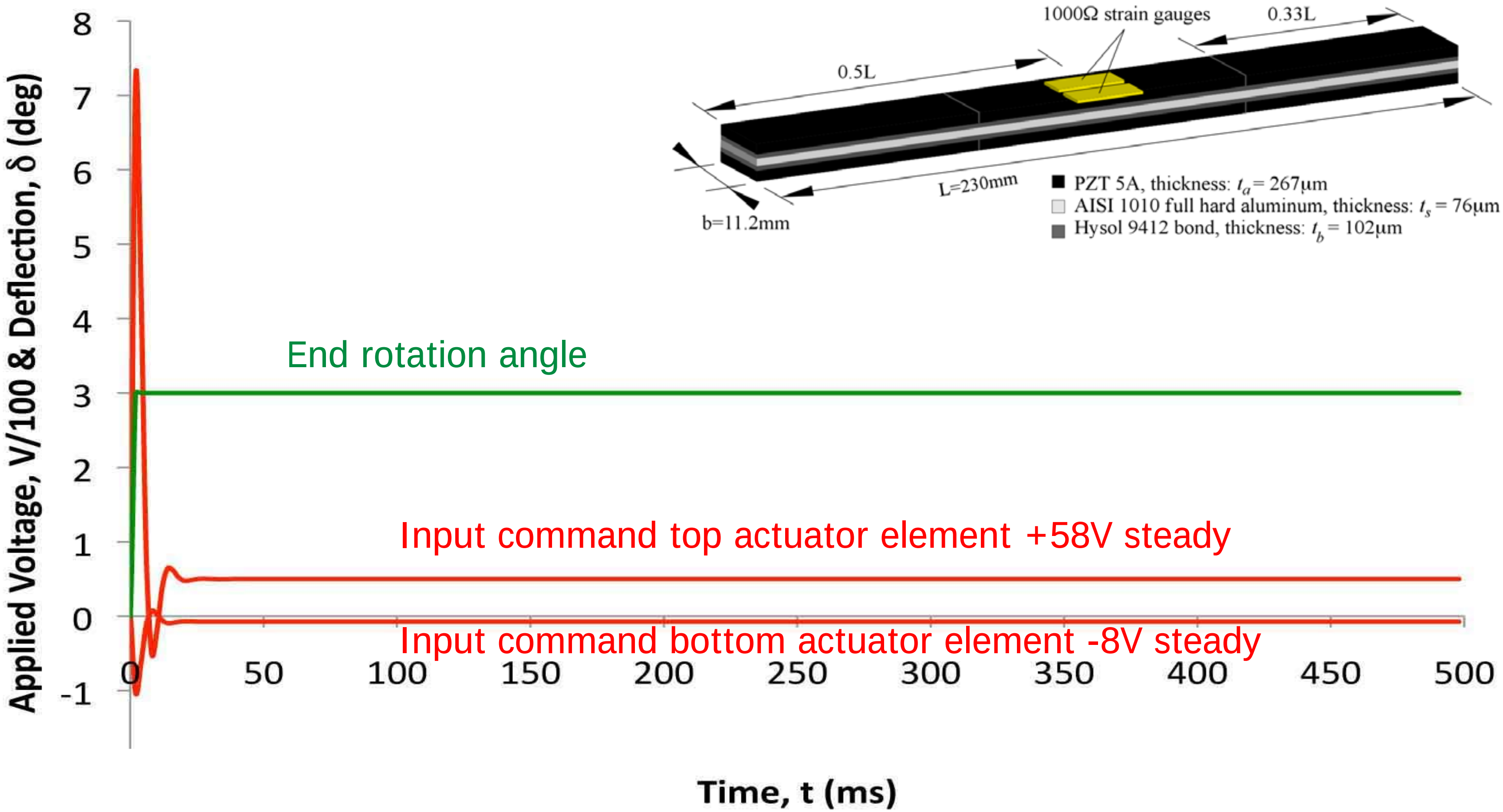


Worldwide patent application: 18 Jan. 2005

PBP Actuators: Real Performance!

Best performance in the adaptive structures industry:

- **1kHz equivalent bandwidth**
- **Driving 0.40 / .50 cal Mach 4.5 canards**

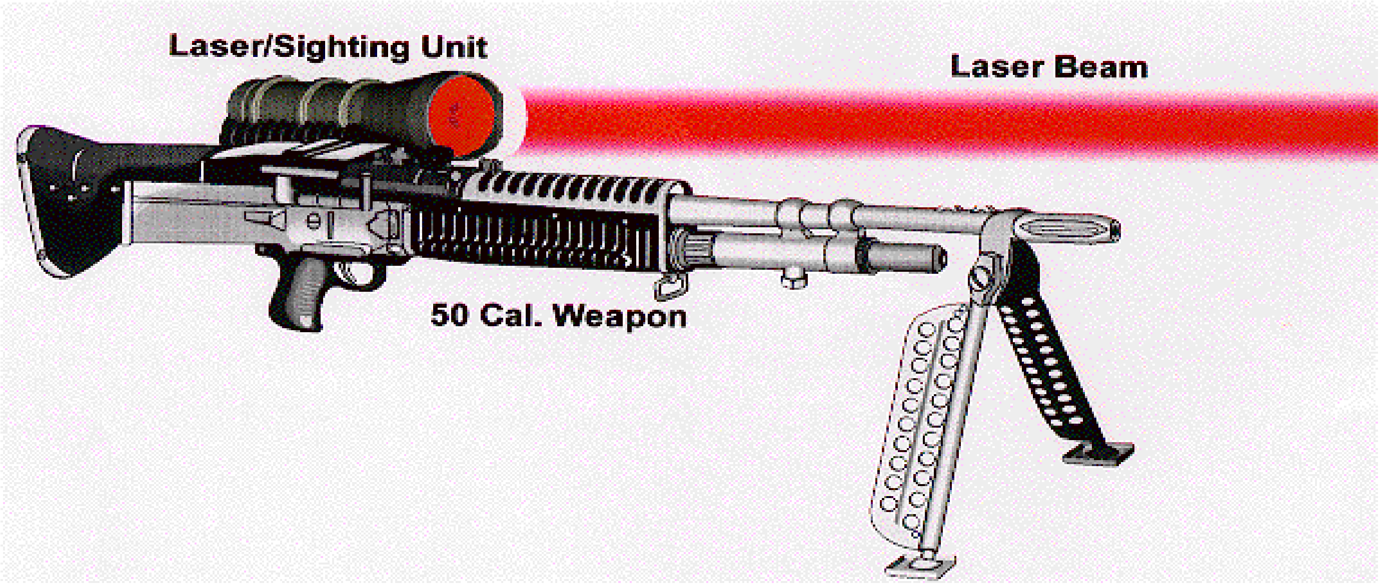


PBP Actuators: What to do with them???

- **Guided rounds of many calibers**

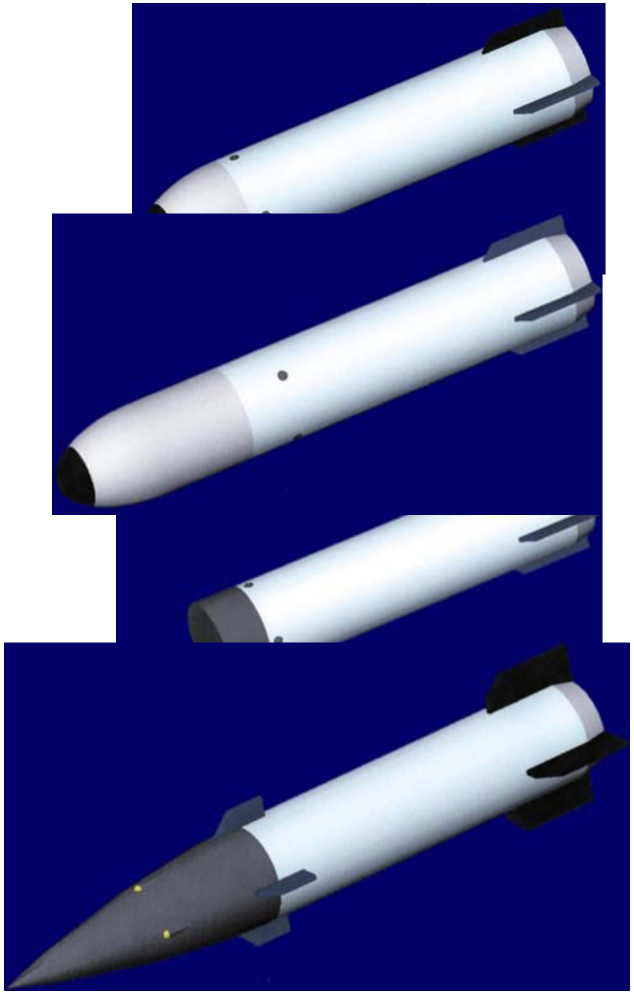
  -Lethal & nonlethal missions

- **Countermunitions**



Families of Steered Piezoelectric Enhanced Adaptive Rounds (SPEARs)

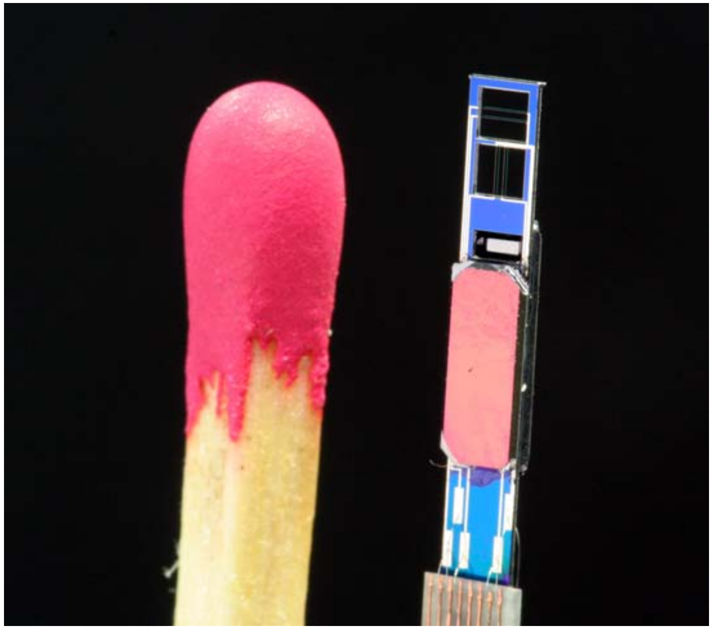
- Roll Stabilized Recon. SPEAR
- Full Control Recon. SPEAR
- Full Control KE SPEAR
- High Maneuverability/ Counterweapon SPEAR



Countersniper with SPEARs & Nanemometers

Nanemometers sense not pressure,

but 3-D particle velocity



R. M. Barrett 8 April 2009 Unclassified Distribution Unlimited

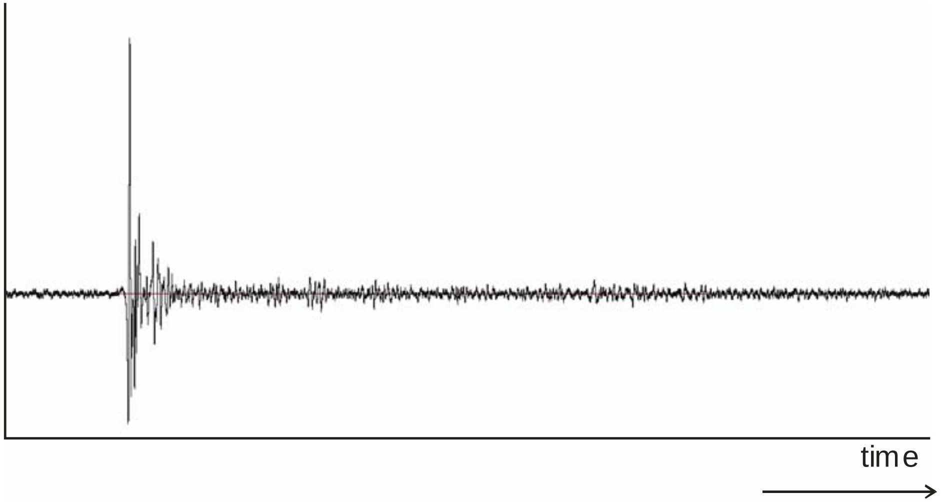
Countersniper with SPEARs & Nanemometers

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

Countersniper with SPEARs & Nanemometers

Gun shot localization

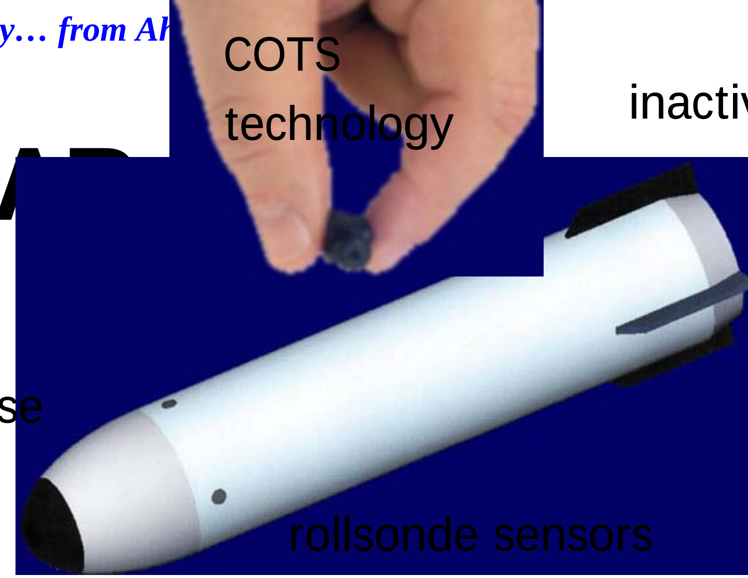
- Real time
- > 1km for hand gun
- Single sensor



Countersniper with SPEARs & Nanemometers

QuickTime™ and a
H.264 decompressor
are needed to see this picture.

Roll Stabilized SPEA



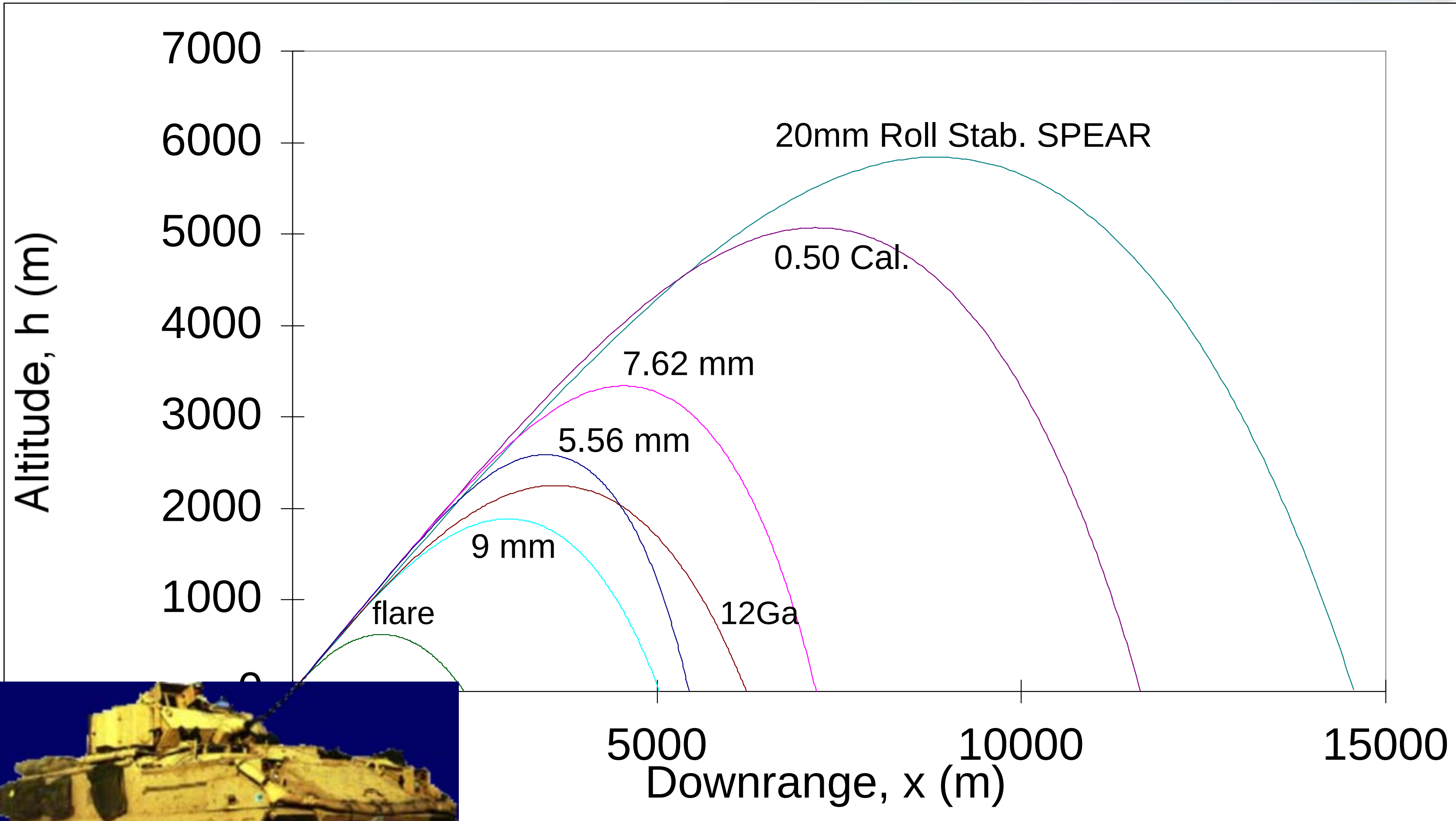
"Look Over the Hill"

Supersonic MAV mission

Tactical Benefits:

- Fastest way to get local reconnaissance images
- Totally impervious to weather/gusts
- ~ $20/round

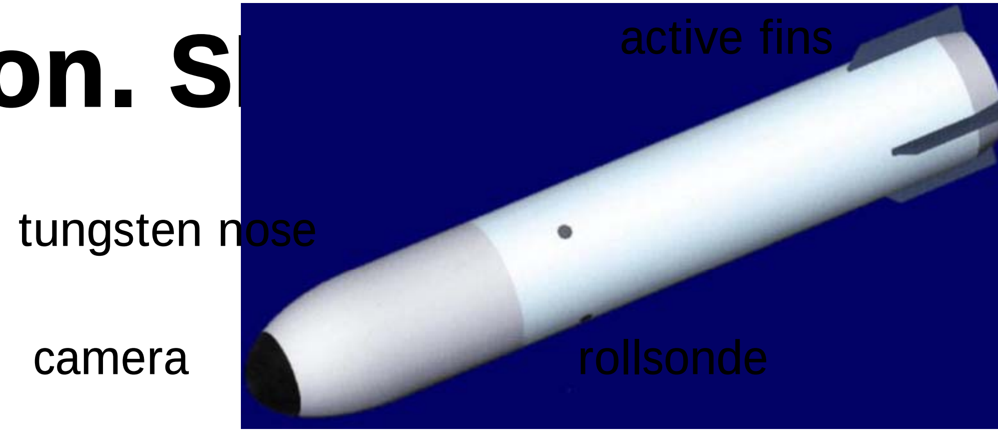
Roll Stabilized Recon. SPEAR

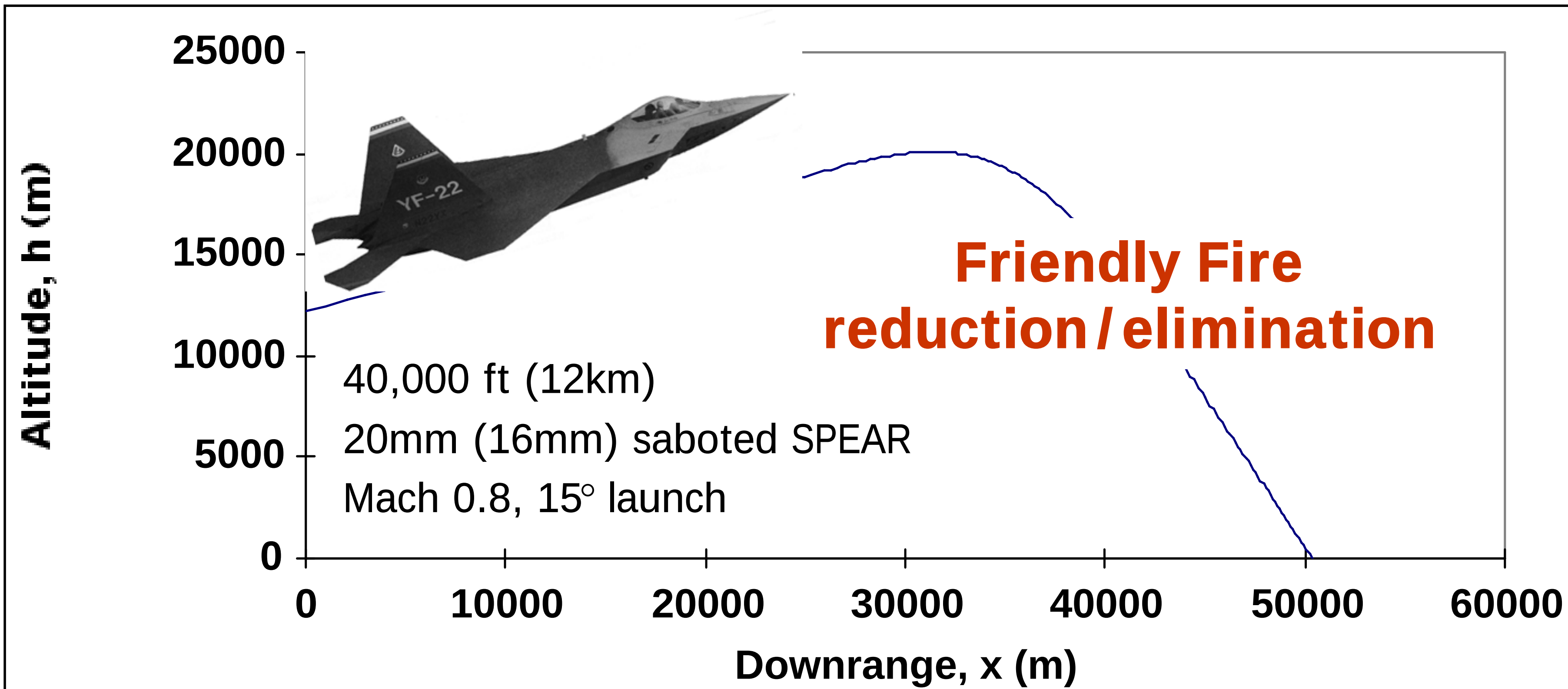


Full Control Recon. S

Full Battlefield

Reconnaissance





Weapon/Counterweapon SPEAR

Weapon mission:

Impart high-g missile performance to hard-launch projectiles

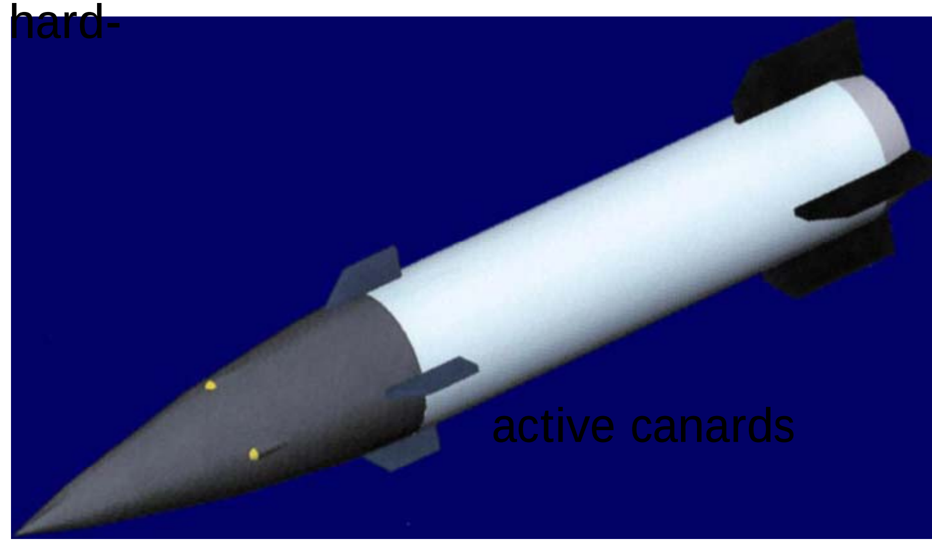
Counterweapon mission:

Defeat all Higher Caliber Weapons

Method:

- Overmatch Bandwidth
- Overmatch Control Authority
- KE and/or HE

inactive fins



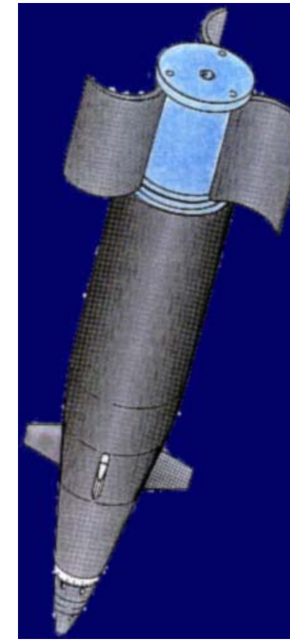
tungsten tangent ogive nose

Counterweapon SPEAR

Selected Missions

Counter artillery

Counter gravity weapon



Air superiority & invulnerability

Transport Protection

High-g sea-skimming missile defeat

Countersniper

Counter small arms

Vehicle & Structure Protection

Sniper Threat Defeat

Change in Gun & Projectile Design Philosophy

Old

- Big Gun w/long rifled barrel
- Highly toleranced barrel
- Stiff barrel
- High tolerance on powder, rounds
- Hard-mounted sight
- Incapable of self-defense mode

New

- Light, smooth barrel gun
- Looser barrel tolerances
- Less stiff barrel
- Insensitive to variations in charge
- Gyrostabilized floating sight
- Can fire unguided, rounds rapidly for self defense

Old

- Unguided, spinning rounds
- Rounds fly ballistically
- Rounds vulnerable to winds, elevation, etc.
- Target moves in 1-3 sec. TOF

New

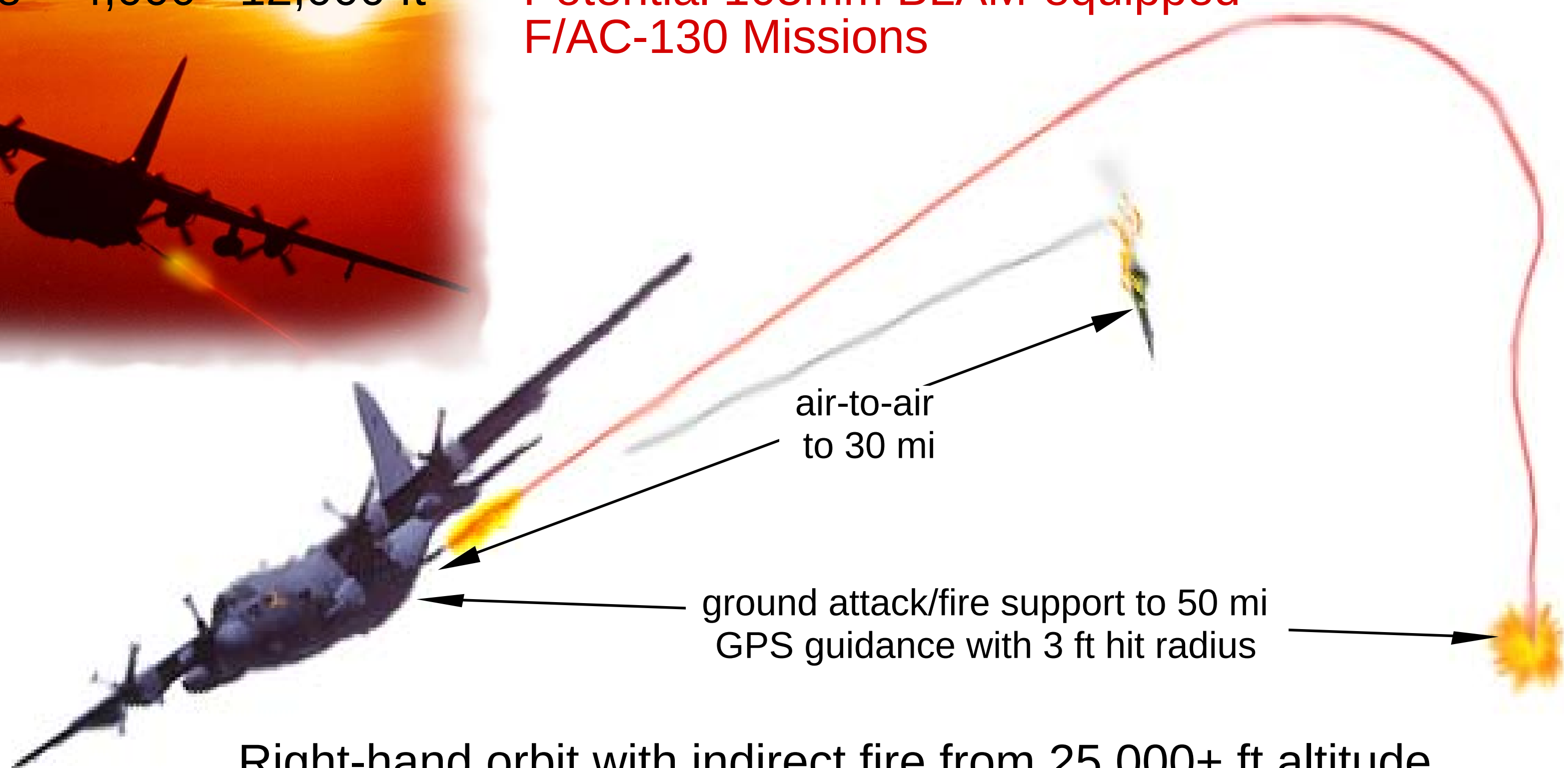
- Guided despun rounds
- Rounds fly flat trajectory
- Rounds insensitive to winds, elevation, etc.
- Target tracked

Guided Indirect Fire Aerial Rounds

Increase stand-off range & accuracy of fire support/ground attack by an order of magnitude

Current/Conventional Approach

Potential 105mm BLAM-equipped F/AC-130 Missions



Right-hand orbit with indirect fire from 25,000+ ft altitude

Questions?

... and a few interesting facts about Kansas...

Hilly, wooded Lawrence, home of the University of Kansas
45 min. West of Kansas City
A very blue dot in a very red state: Lawrence ~ Kansas as Austin ~ Texas

Transportation Hub, Flight Test
Light Aircraft Manufacturing

Avionics

R&D, Flight Test, Aircraft Design
Missiles, Munitions, UAVs

Airline Aircraft Maintenance
Insurance
Spares
Interiors
Avionics
Salvage
Airframe Design, Development, Production

Hovering Missiles: New Tools for Target ID, Interior Precision Strike, Friendly Fire Mitigation and Persistent Suppression

Professor Ron Barrett
Director of the Adaptive Aerostructures Laboratory (AAL)
Aerospace Engineering Department
The University of Kansas, Lawrence, Kansas USA

AAL ...Backroom for the Innovation-Driven Aerospace Organizations of the world...

44th Annual Gun and Missile Systems Conference & Exhibition
Hyatt Regency Crown Center, Kansas City, MO
8 April 2009

Purpose:

- ***Expose the Munitions Community to the blurring line between missiles, munitions & UAVs.***

- ***Describe advanced weapon systems which are technically feasible Today.***

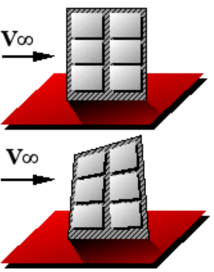
Outline:

I. History of Underpinning Programs

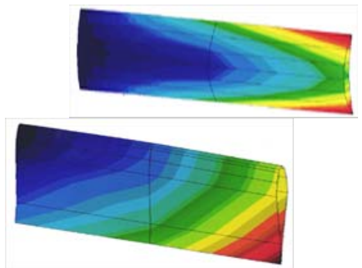
II. Current Platform Configuration

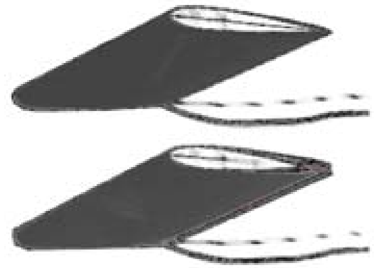
III. New Missions…
Revolutionary Capabilities

Background in Flight Control



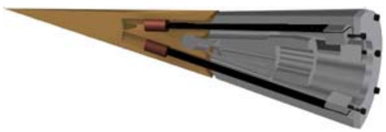
Twist & camber-active subsonic & supersonic wings





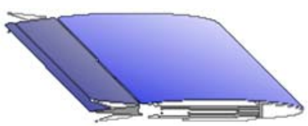
1st Pitch-Active Missile Fins

1st Adaptive Gun-Launched Munitions

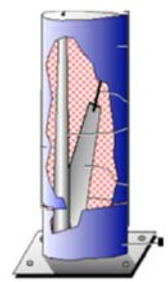


1st Adaptive Gravity Weapons

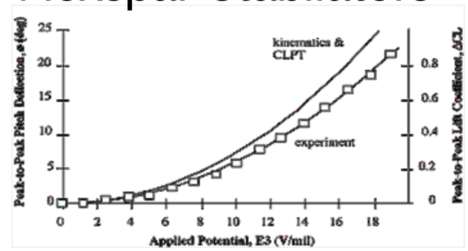
1985 1990 1995



Twist-active plates & flaps

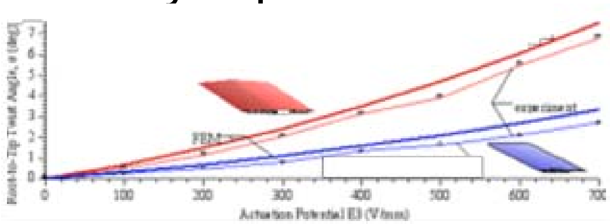


Flexspar Stabilators



Crawley, Andersen, Spangler, Hall, Lazarus (MIT)

Good theory-experiment correlation



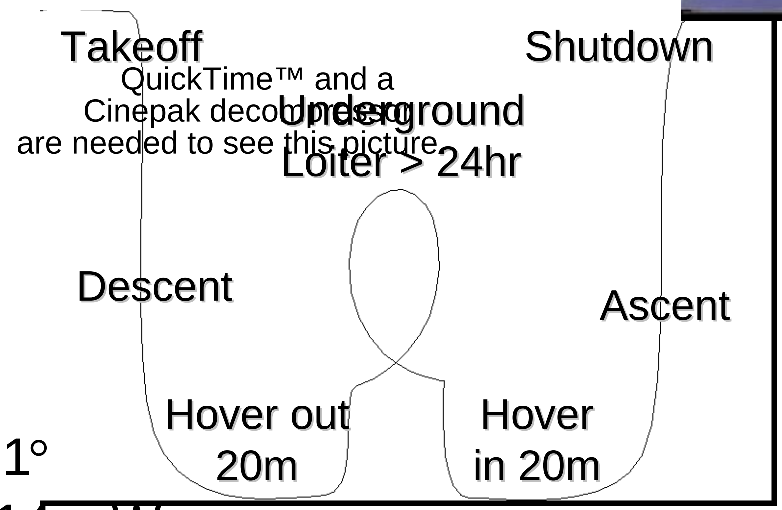
1st Flying Adaptive UAV

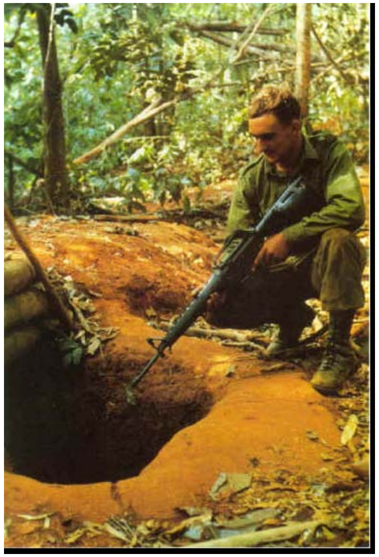
VTOL Approach to Urban UAV Flight: 1994 - 1997 The First MAV, Kolibri

The 1st Micro Aerial Vehicle -- by the DoD CounterDrug Technology Office

Enabled by Flexspar Piezoceramic Stabilators

Mission Profile:



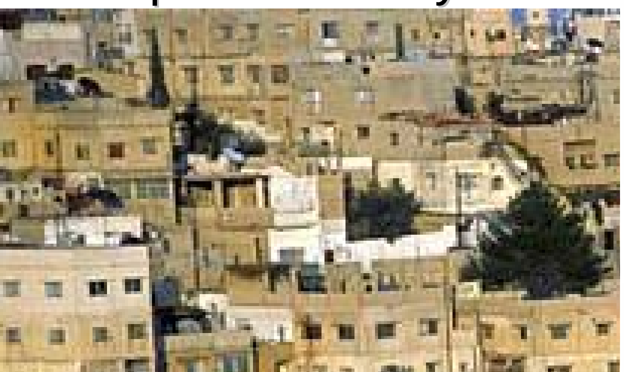


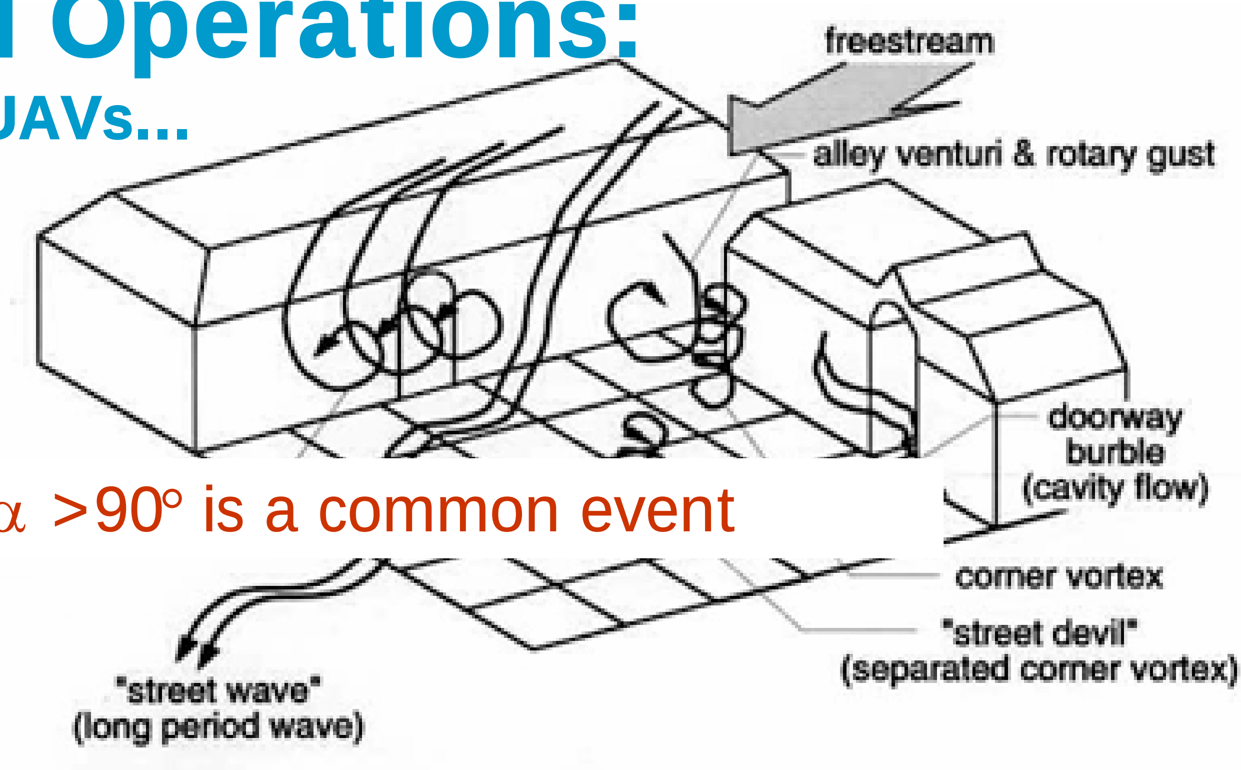
- total mass 5.2g
- actuator mass: 380 mg
- max. static deflections: ±11°
- max power consumption: 14 mW
- pitch corner frequency: 47 Hz
- first natural frequency in pitch: 23 Hz

Low-Level Operations:

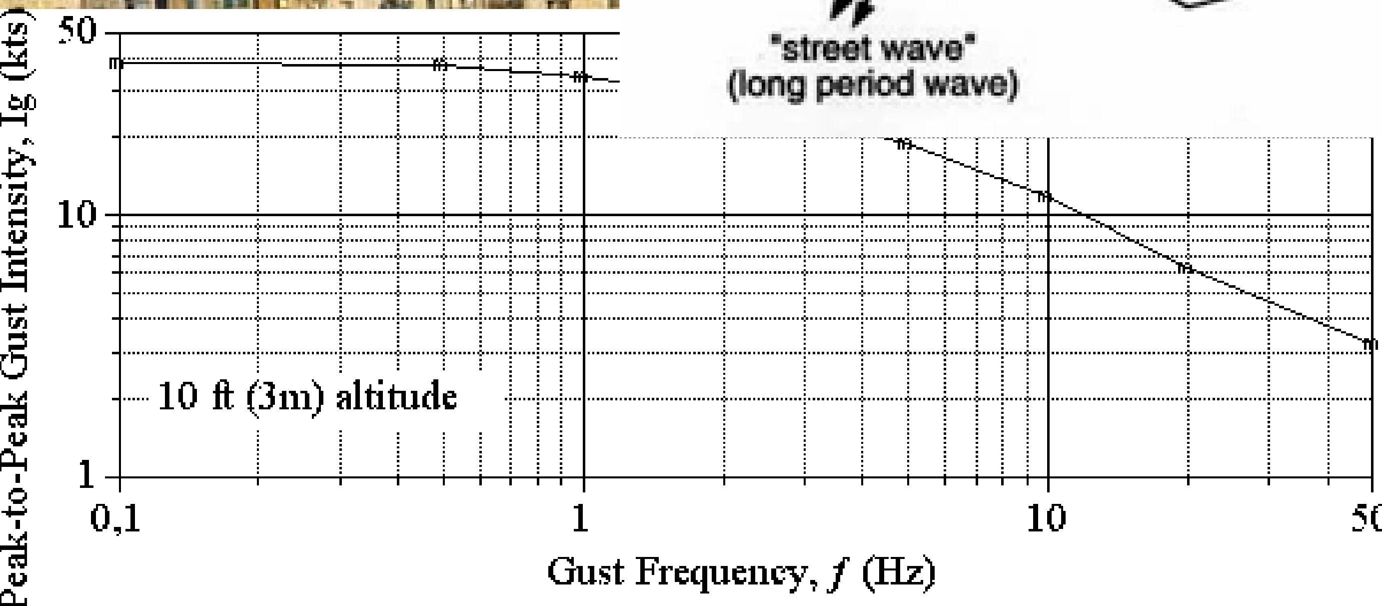
Serious trouble for UAVs…

DARPA Urban & Sub-Canopy Atmospherics Survey 1998



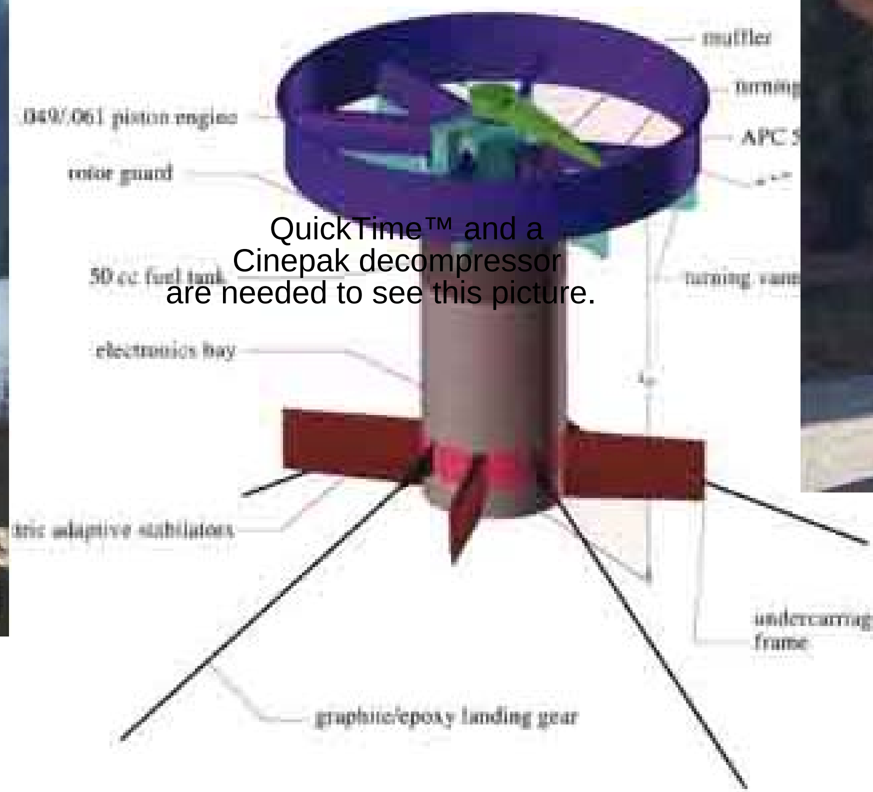


α >90° is a common event



First Free-Flight VTOL MAVs

6” (15cm) VTOL Coleopter



QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

DARPA
1999 - 2000
Flyoffs @
MacDill &
Quantico

More conventional UAV "Challenges"

Operation Allied Force Kosovo 1999
(source: Yugoslav armed forces)

UAVs Lost in Kosovo:

Britain: 14 (14 Phoenix)

United States: 17 (3 Predators, 9 Hunters, 4 Pioneers, 1 UAV of undetermined type)

Germany: 7 (presumably all CL-289 turbojet drones)

France: 5 (3 Crecerelle, 2 CL-289)

By Jan. 2003, 30 of 70 RQ-1 Predators crashed or were shot down
(source: Mike Mount CNN Washington Bureau)

4 UAVs of undetermined origin (possibly U.S., German, or Italian)

Advanced / Hypermaneuverable UAVs:

Why?? … & the Role of Adaptive Aerostructures

"2/3 of eligible targets went undetected, let alone unengaged because of our reconnaissance deficiencies."

"Folks… it's going to take something new to fix this problem."

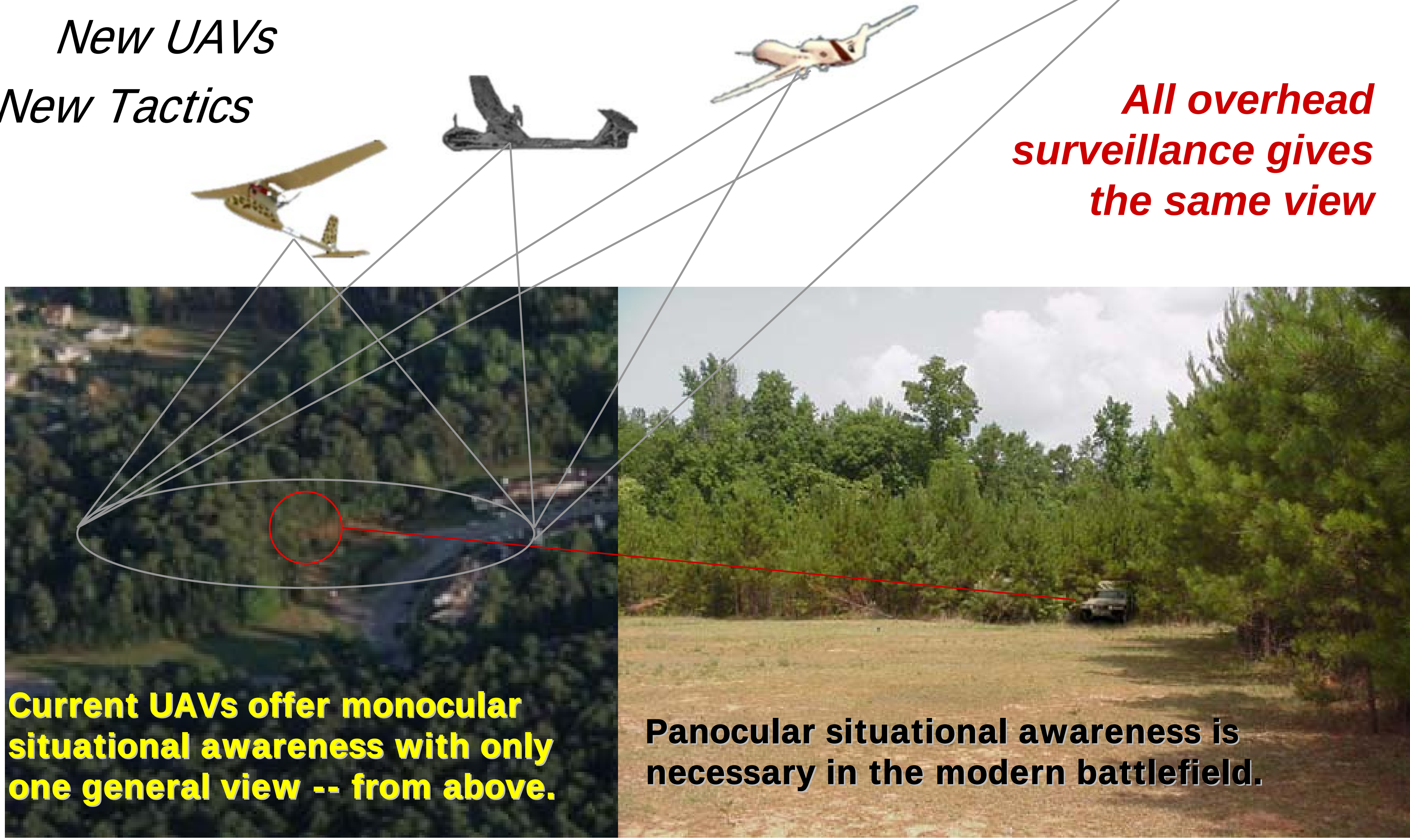
-Lt. Gen. Bruce Knutson, USMC

Low-Level UAV Ops Challenge:

New UAVs

New Tactics

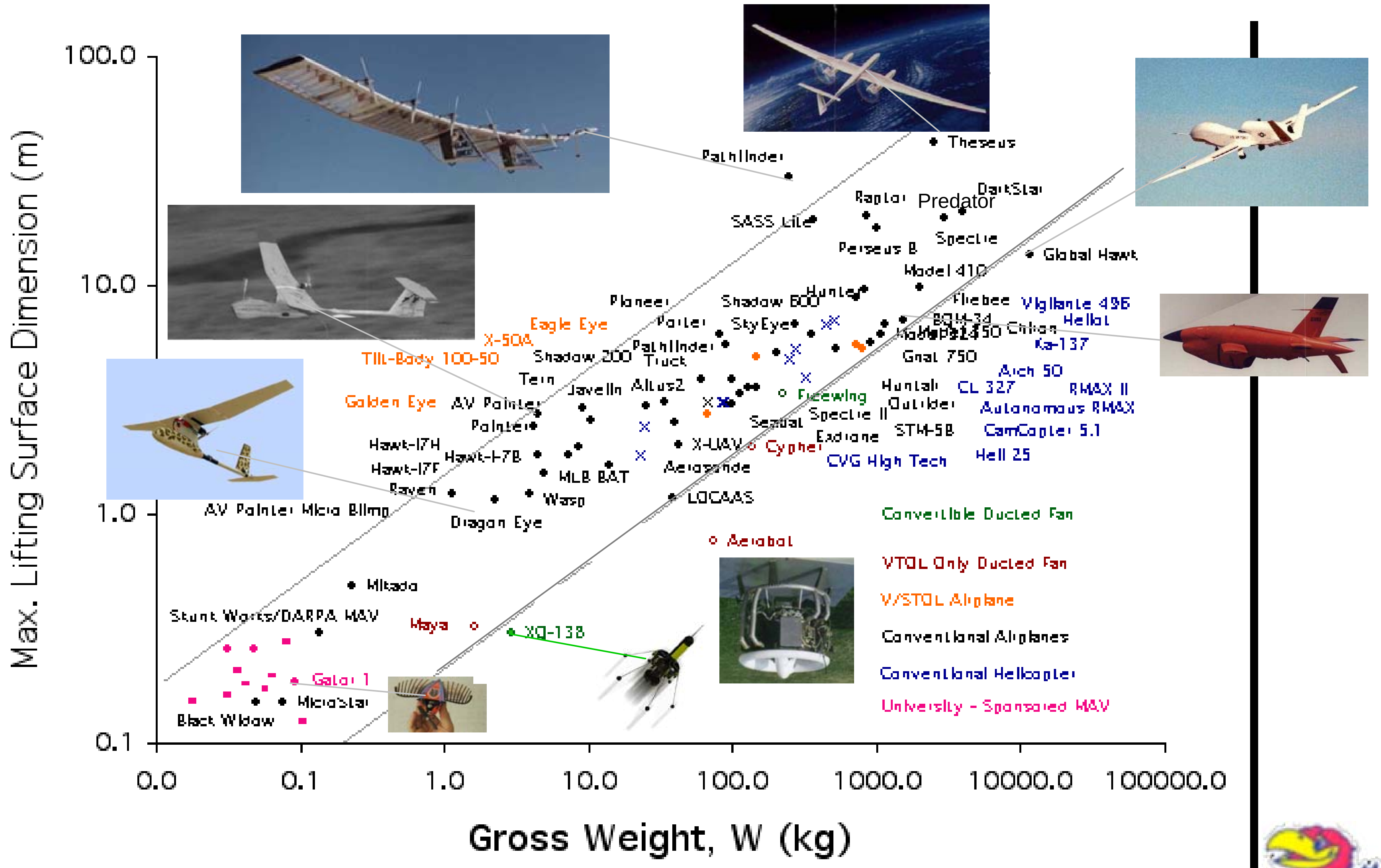
All overhead surveillance gives the same view



Changing UAV Operations

Sharing Airspace -- the fight at altitude

Current UAV Market



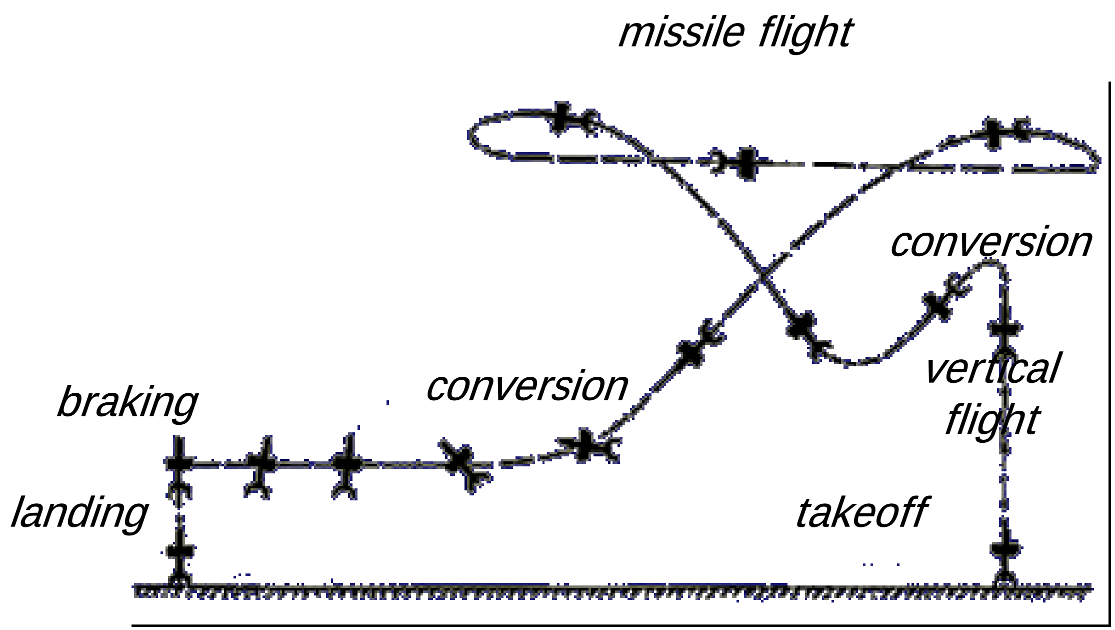
Honeywell's
"Micro Aerial Vehicle" (MAV)
or
"Organic Aerial Vehicle" (OAV)

QuickTime™ and a
MPEG-4 Video decompressor
are needed to see this picture.

Paradigm Shift…
Hypermaneuverable UAVs

Hover in more places than a helicopter

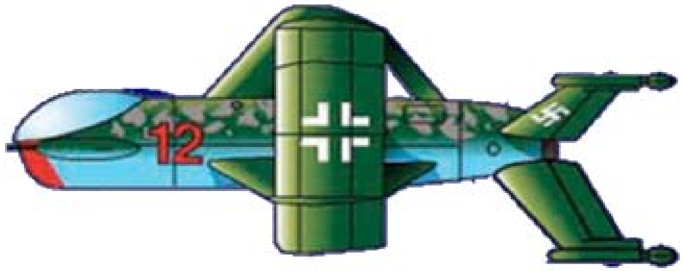
Fly as fast as a missile



Convertible Coleopter Configurations

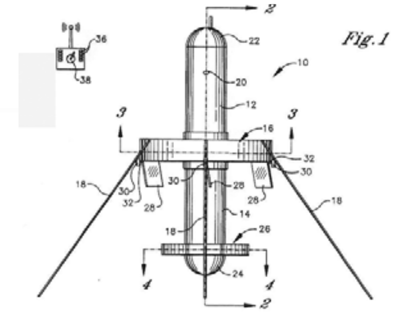
Heinkel Wespe 1944
(concept only, never built)

Heinkel Lerche 1944 (concept only, never built)



R. M. Barrett 11 February 2009 Unclassified Distribution Unlimited

US Pat. 6,502,787

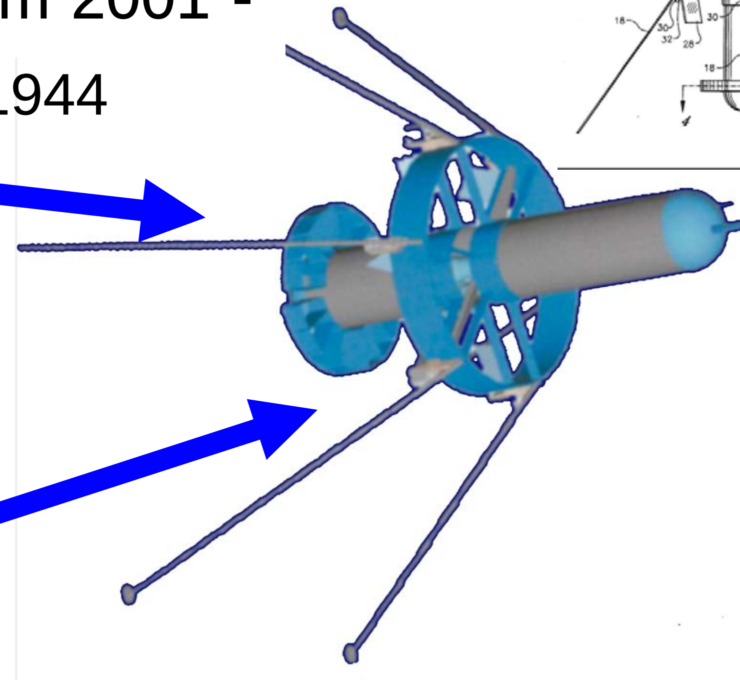


Hypermaneuverable UAVs

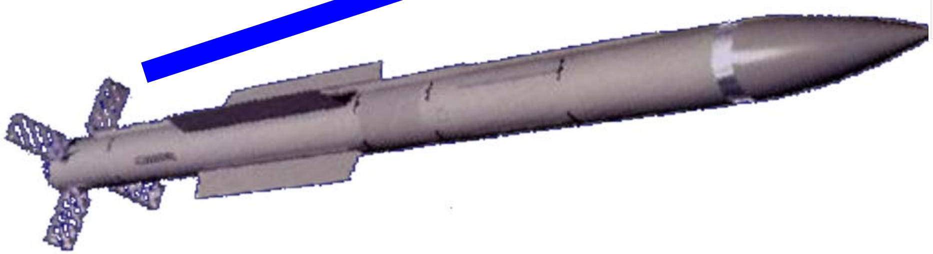
XQ-138 Program 2001 -

Heinkel Wespe 1944

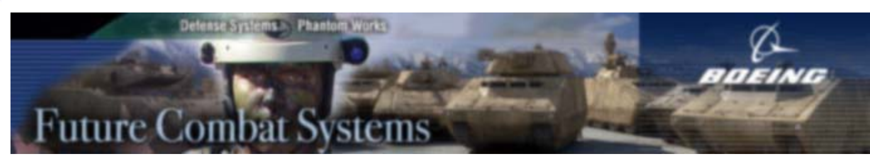
more control authority needed for MOUT environment



AA-12 (R-77)
(Aamraamski)



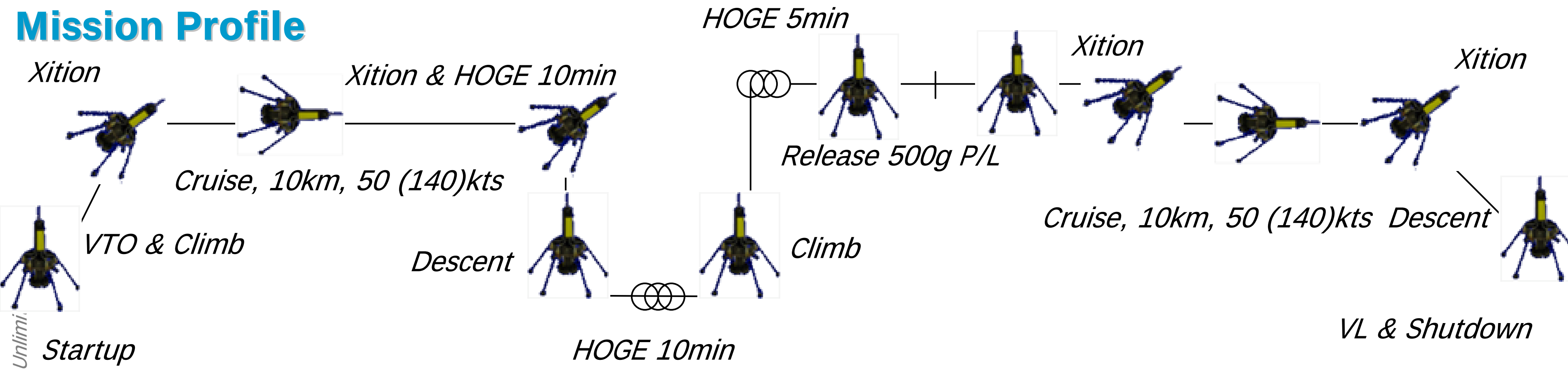
high control authority grid/lattice fins



Singapore Technologies Aerospace

XQ-138 Hypermaneuverable UAV

Mission Profile



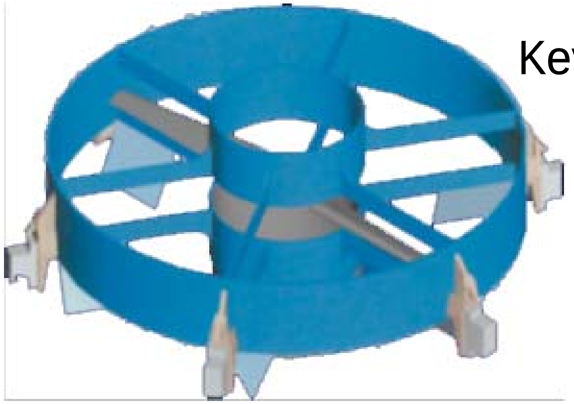
Mission Specification:

- Max. gross weight: 6.8lb (3.1kg)
- Max.payload weight: 2.2 lb (1kg)
- All weather capable
- 12”/hr (31cm/hr) rain
- 25+ kt gust penetration
- Sensors: B/W 0.001 lux, Color 0.1 lux,FLIR
- Sandstorm capable to 100kts
- Vmax 140kts for 1hr (blue sky)
- -40/100°F (38°C), 100% humidity
- Combat shotgun resistant @5m
- 15g MOUT wall strike
- Land + autostart
- Flight modes: 1st, 3rd person, fully autonomous w/waypoint nav.

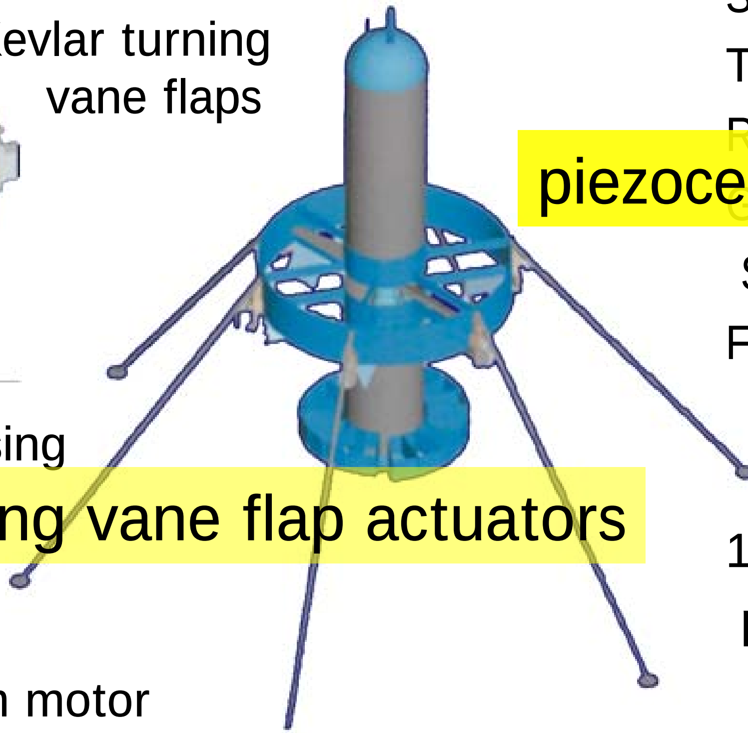
XQ-138

MDO using best currently available technology

ballistic graphite & boron structure



Kevlar turning
vane flaps



Sensor
Transmitter
Receiver
GPS navigator

piezoceramic gyros

SAS system
Fuel tank

titanium powerplant housing

piezoceramic turning vane flap actuators

1.3hp (970W)
powerplant

magnesium motor
mount/fuselage coupler
flight control actuators

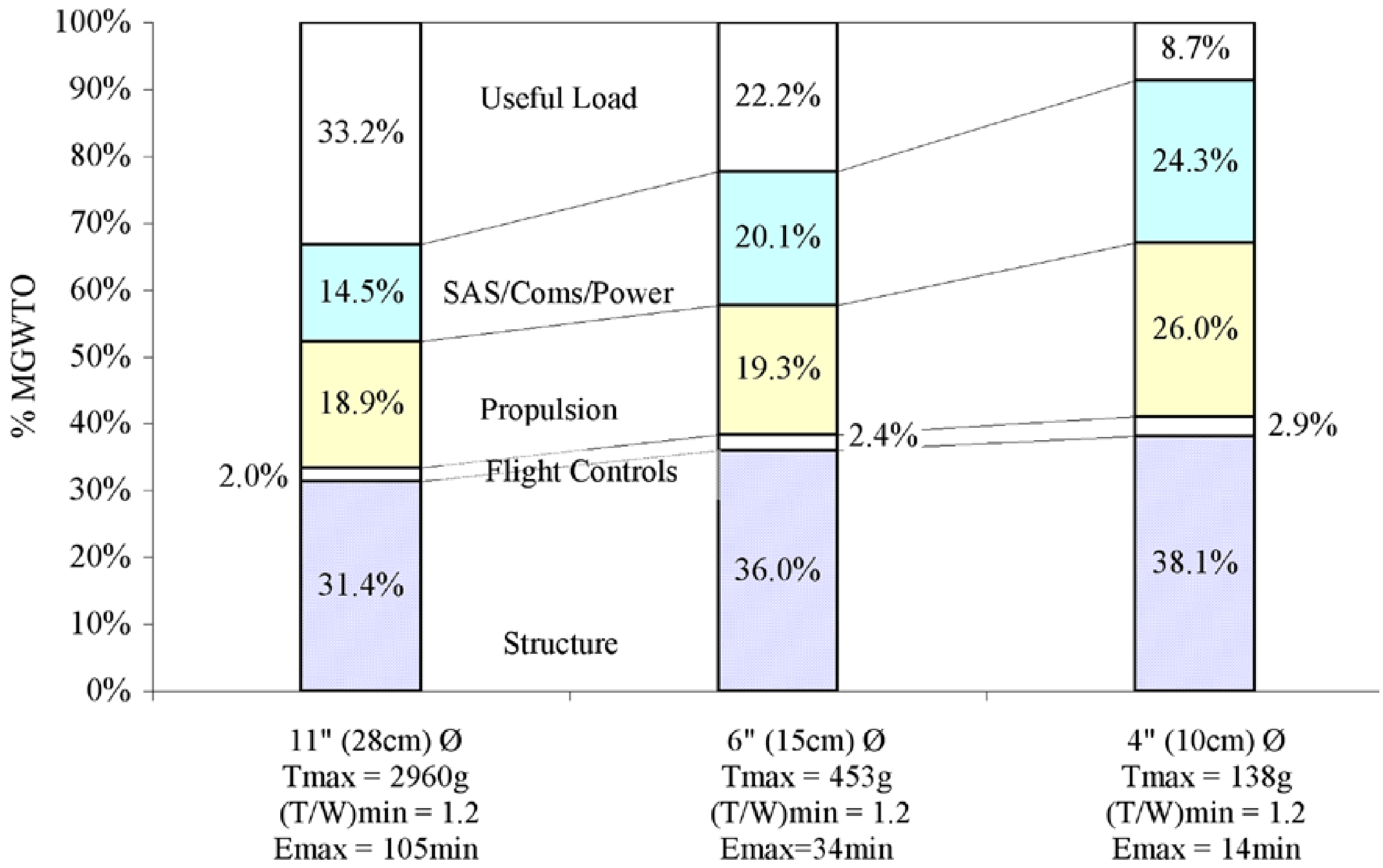
Muffler ass'y

graphite racking grid fins

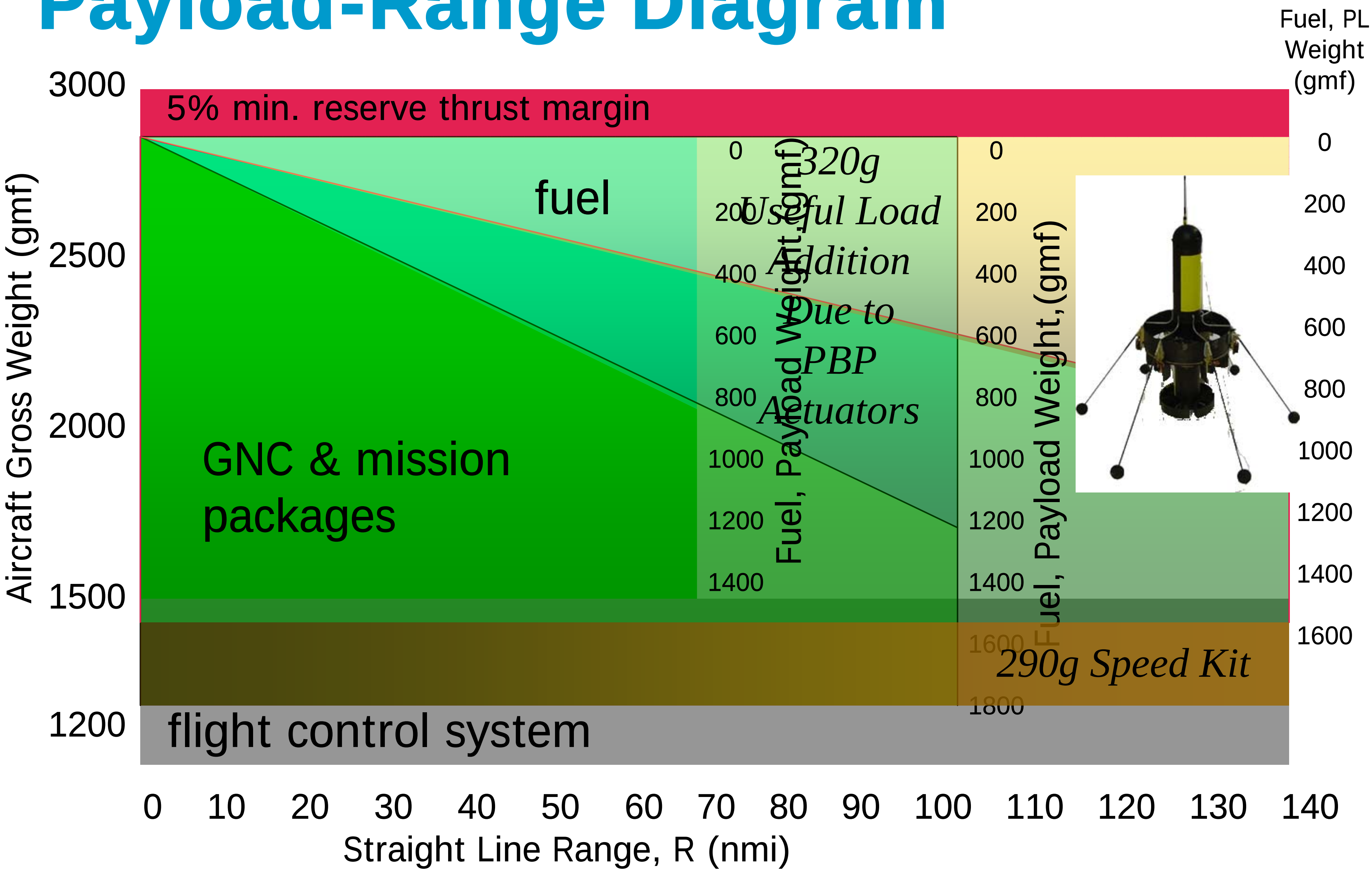
piezoceramic grid fin actuators

XO-138 Weight Fraction Trends…

Adaptive FCS



Payload-Range Diagram



Flight Testing

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

New Mission Testing…
Redstone Arsenal, AL

Demonstration of stable launch, transition, missile-mode flight, stable hover and recovery

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Remote Launch from Remote Controlled Armored Vehicle

Redstone Arsenal

New Mission Testing…
Eglin AFB, FL, Hellfire Range

BDA following Javelin Missile

Live Fire Shot against a T-60

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Launch and Target ID against Ground Target

Stalking Hovering Missile Flight Demonstration

XQ-381 Mission Profile & Spec. 40mm Weaponized Aircraft

40mm Recoilless

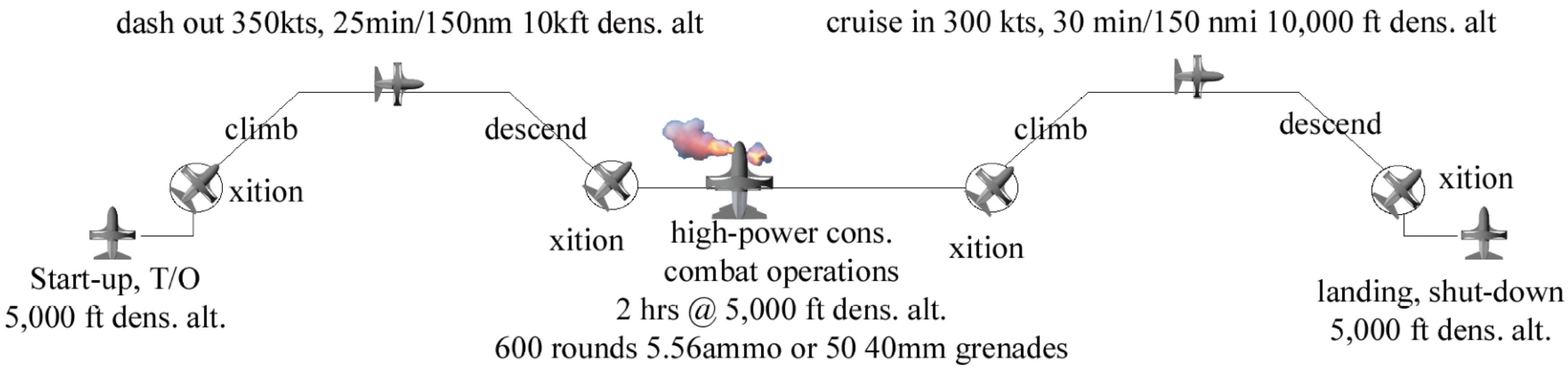
Munition Shots

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Now where???

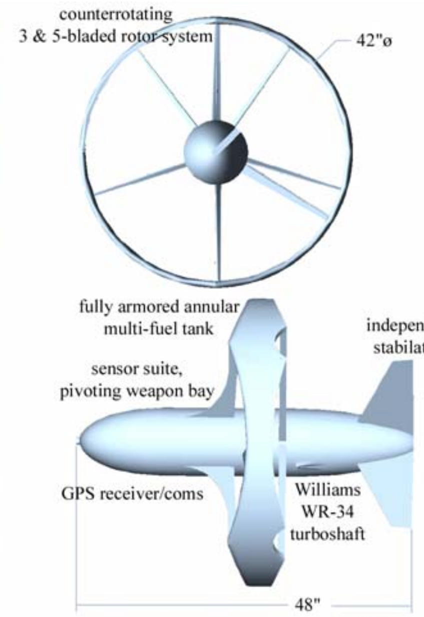
FAQ-381 Hypermaneuverable Collocated Close Air Support (CCAS) Hovering Missile

The Next Generation: FAQ-381

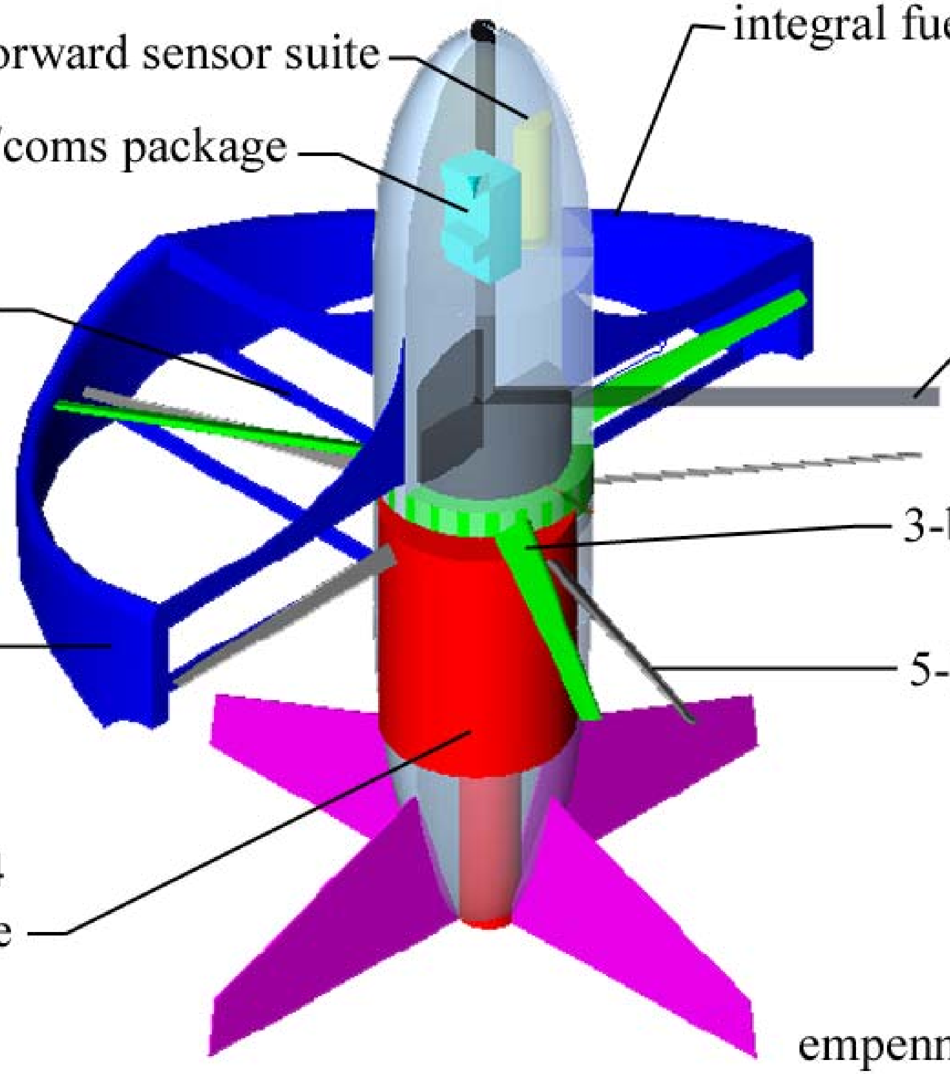


Enhanced Mission Specs:

- MGWTO ~50 lb
- Vmax >380kts
- >3hr HOGE
- >5hr Vbr Loiter
- Large Sector Coverage
- Full sensor & coms suites
- Collocated Close Air Support
- Combat resistant



The Next Generation: FAQ-381



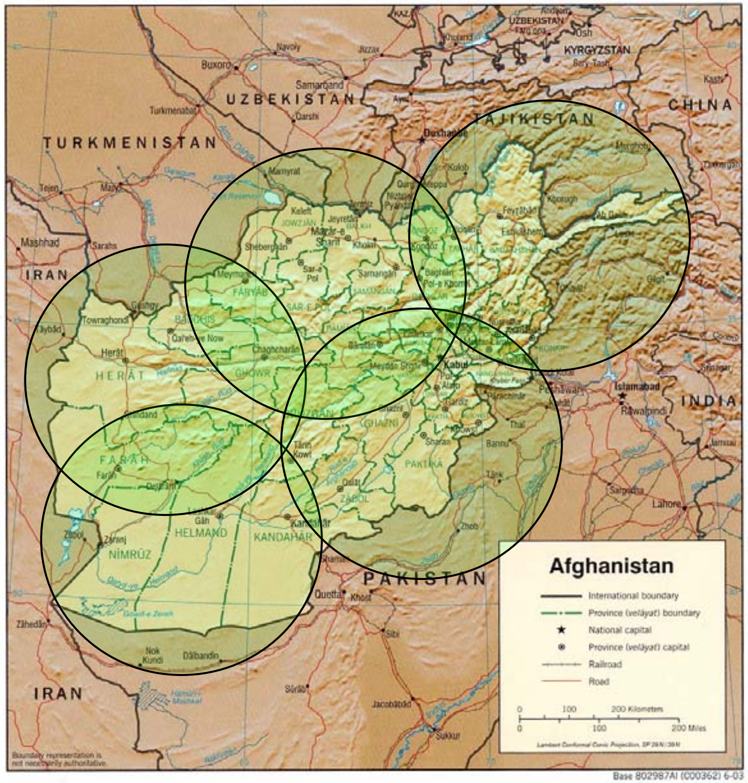
The Next Generation: FAQ-381 CCAS

Iraq:

4 Base Coverage for 20min Response

Afghanistan:

5 Base Coverage for 20 min Response



The Next Generation: FAQ-381 CCAS

Tankers enable "indefinite" loiter / orbit

The Next Generation: FAQ-381 5 min CCAS

9 Track Coverage for Iraq

10 Track Coverage for Afghanistan

Precision Autorecovery

Sub-millimeter navigation precision, exacting stabilization, gust insensitivity

QuickTime™ and a
Cinepak decompressor
are needed to see this picture.

Questions?

Joint Development of a Non-Magnetic Azimuth Sensor for Dismounted Targeting Operations in All Environments

NDIA 44th Annual Gun & Missile Systems Conference & Exhibition

8 April 2009

Kate Jones
NSWC Dahlgren

Overview

- Problem with Current Azimuth Sensors for the Dismounted User
- Key Performance Parameters
- Joint Approach to Obtaining a Solution
- Azimuth & Vertical Angle Measurement (AVAM) Joint Working Group (JWG)
- Path to AVAM JWG Success
- Schedule of Joint Development Efforts
- Pros & Cons of Current Solutions

The Task

- What Are We Trying to Do?
  - We are attempting to develop a High Accuracy, Non-Magnetic Azimuth & Vertical Angle Module
    - Joint, Long Term Goal: To Support Joint Effects Targeting System (JETS) with production in 2014
- Why?
  - **Magnetic anomalies, especially ON the User, are common** and result in potentially significant Target Location Error (TLE). Majority of cases, the **User is unaware of the interference**.
    - Current gear in the field causes azimuth errors of up to 150 mils!
  - GPS guided munitions require more accuracy than is available in current dismounted targeting sensors
    - Require <20m (T), <10m (O) according to Naval Surface Fire Support requirement

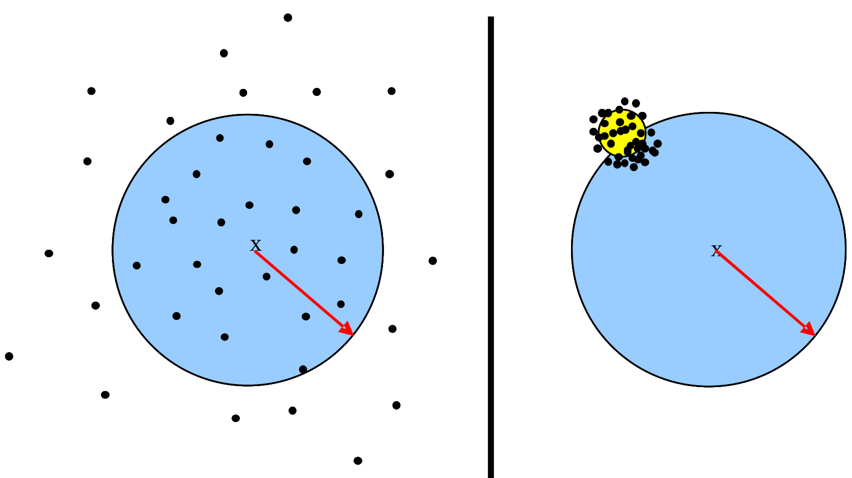
JDAM

Excalibur

- **Users are unaware of magnetic anomalies caused by their gear which affect azimuth error by up to 150 mils**
- **Munitions have already been fielded requiring a solution within as short a timeframe as possible**

Target Location Error Definition

Target Location Error 50 (TLE50): *TLE50 is a measure of deviation from the actual location of a target and defined as the radius of a circle which is centered at the actual target coordinate in which 50% of the observations are contained.*



Current technologies allow the User to very precisely miss targets.

Old Targeting System
Old Weapon System

Old Targeting System
New Weapon System

Key Performance Parameters

Key Parameter	Near-Term External / Tripod Mount Threshold (T)	Long-Term Internal / Fully Integrated Objective (O)
Azimuth Accuracy	*±4 mils Probable Error (PE)*	*±1 mil PE*
Vertical Angle Accuracy	*±4 mils PE*	*±1 mil PE*
Orientation Range	Pitch: ±500 mils (~30°) Bank: ±270 mils (~15°)	Pitch: ±1511 mils (~85°) Bank: ±500 mils (~30°)
Slew Rate	30° per second	1000° per second
Set up Time	*< 180 seconds*	< *1* second
Operational Temperature	-40°C - +70°C	-40°C - +70°C
Shock	40g / 11 ms	2000 g / 1.5 ms (weapon fire)
Vibration	MILSTD 810/ min integrity	MILSTD 810/ min integrity
Volume	*≤50 cu in*	*≤0.25 cu in*
Weight	*≤4.0 lbs (≤2.0 lbs preferred)*	*≤0.2 lbs*
Power	*≤10.0 W (≤2.0 W preferred)*	*≤250 mW*
Average Unit Production Cost (FY07 dollars)	*$20K*	*TBD*

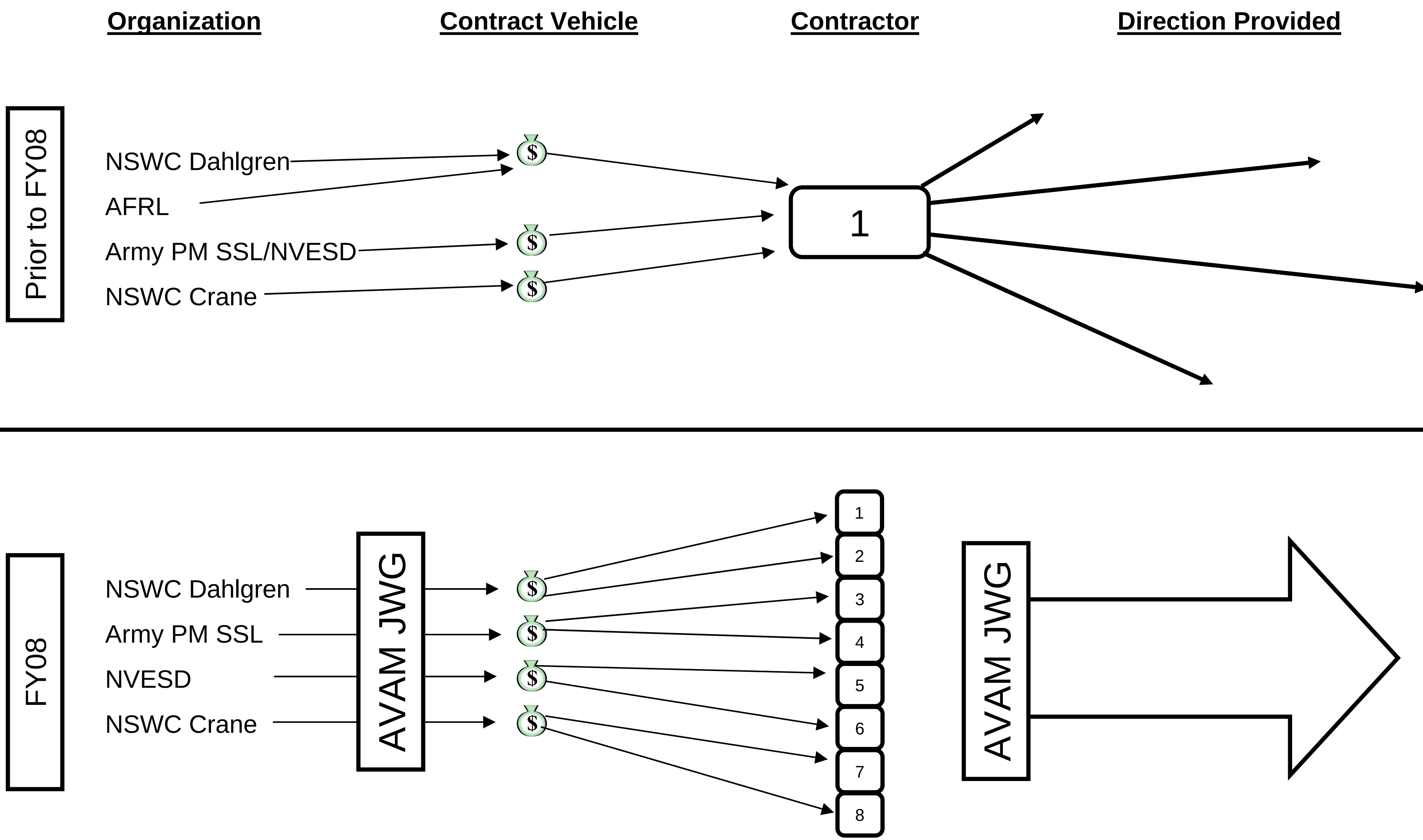
AVAM JWG Participants

- Naval Surface Warfare Center (NSWC), Dahlgren Division (Chair)
- Army Product Manager (PM) Soldier Sensors & Lasers (SSL)
- Office of Naval Research (ONR)
- Marine Corps Systems Command (MCSC) Program Manager (PM) Fire Support Systems (FSS)
- Night Vision & Electronic Sensors Directorate (NVESD)
- Johns Hopkins University (JHU) / Applied Physics Lab (APL)
- NSWC, Crane Division
- Air Force Research Lab (AFRL)
- Defense Advanced Research Projects Agency (DARPA)
- Marine Corps Warfighting Lab (MCWL)

AVAM JWG History

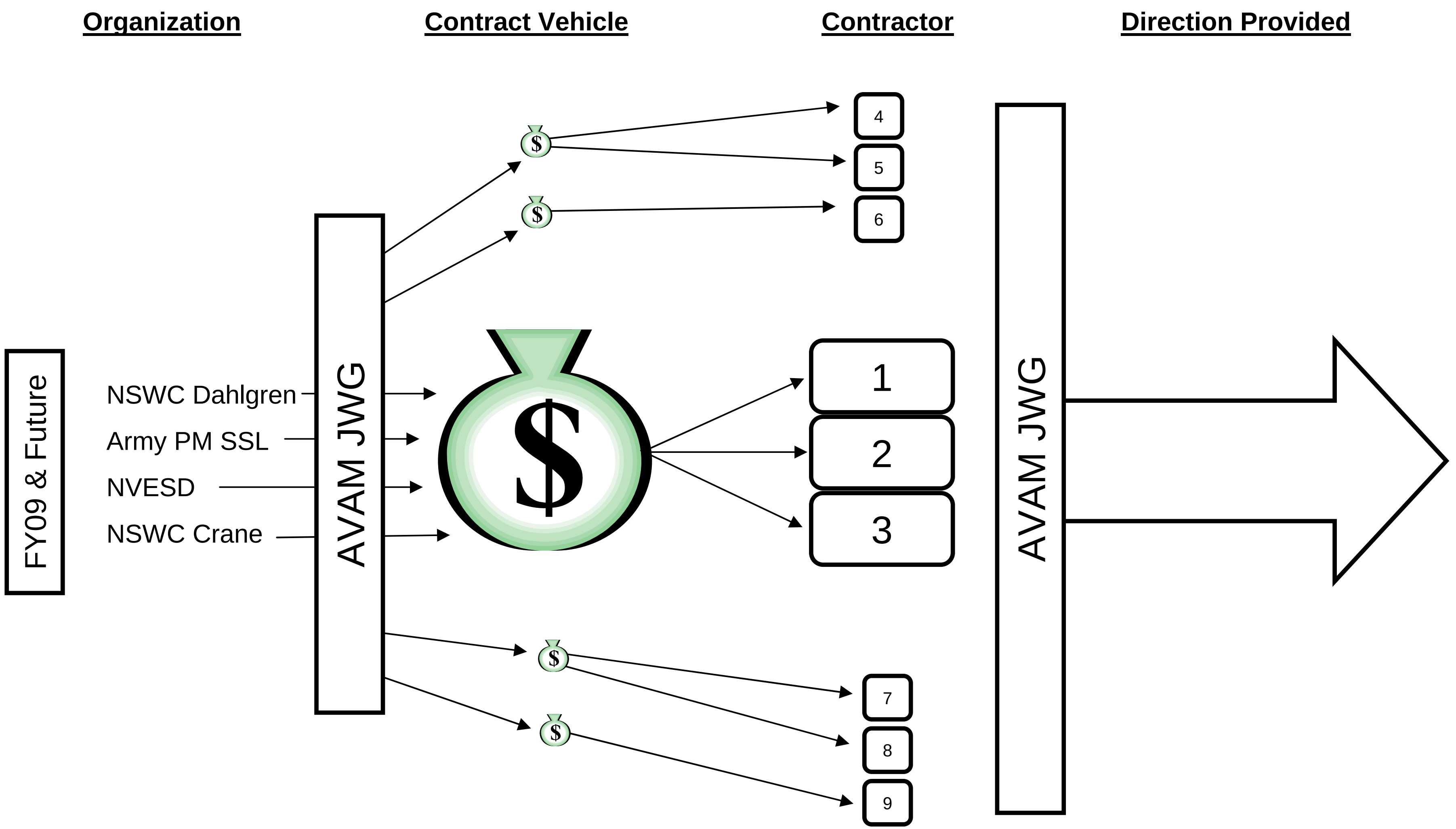
- Government funded efforts laid a foundation for current collaboration
  - Limited coordination across DoD resulted in duplication of efforts
  - Spurred initiation of quarterly JWG meetings
- The 2007 Joint Precision Azimuth Sensing Conference (JPASC)
  - Opportunity for ALL government stakeholders to listen to industry representation
  - Determine what progress was being made in the field of azimuth sensing
  - Present unified front to industry and demonstrate the need & market for azimuth sensing
- Close collaboration between Naval Surface Warfare Center (NSWC), Marine Corps Systems Command (MCSC) Program Manager Fire Support Systems (PM FSS), Office of Naval Research (ONR) 30 (Fires), Army Product Manager Soldier Sensors & Lasers (PM SSL), Night Vision & Electronic Sensors Directorate (NVESD), Special Operations Command (SOCOM), Johns Hopkins University / Applied Physics Lab (JHU/APL), and others (2007-present)
  - Several development efforts underway to meet a joint requirement for a non-magnetic azimuth sensor
  - Collaboration during proposal evaluation prevented duplication of efforts
  - Joint attendance encouraged at status meetings with contractors

AVAM JWG Evolution



CONCEPTUAL PURPOSES ONLY

AVAM JWG Evolution (cont.)



CONCEPTUAL PURPOSES ONLY

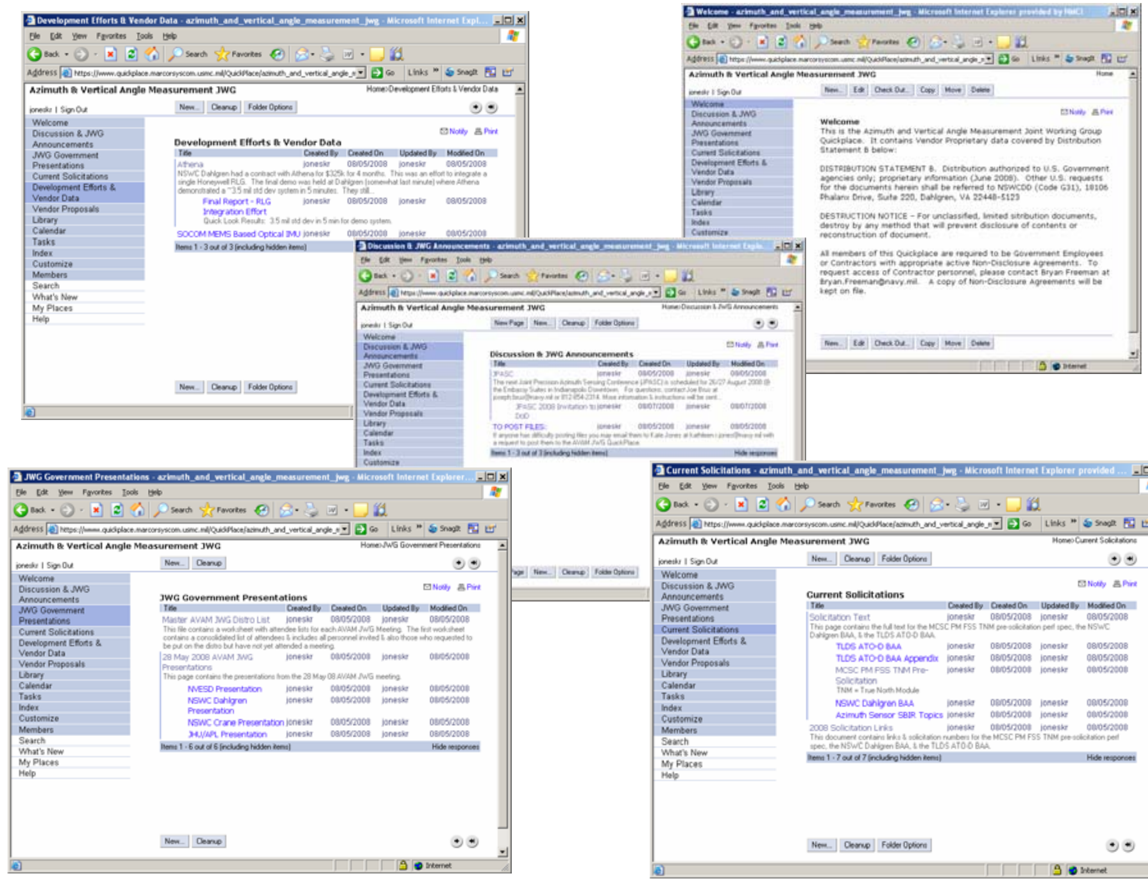
Path to JWG Success

- Significant effort & vigilance by all involved is required to establish & maintain joint forum
  - Frequent & open communication
  - Quarterly JWG meetings
  - Joint proposal evaluations
  - Joint attendance at contractor status meetings
  - Report distribution
  - Joint demonstrations / tests
  - JPASC / industry days
  - Tools for sharing information
- Set aside differences early
  - Goal is to find a solution, regardless of funding source
  - Define common requirements
  - Acknowledge differences in implementation
  - No feelings of ownership towards specific technologies

Deliberate collaboration is required to achieve a successful Joint Working Group

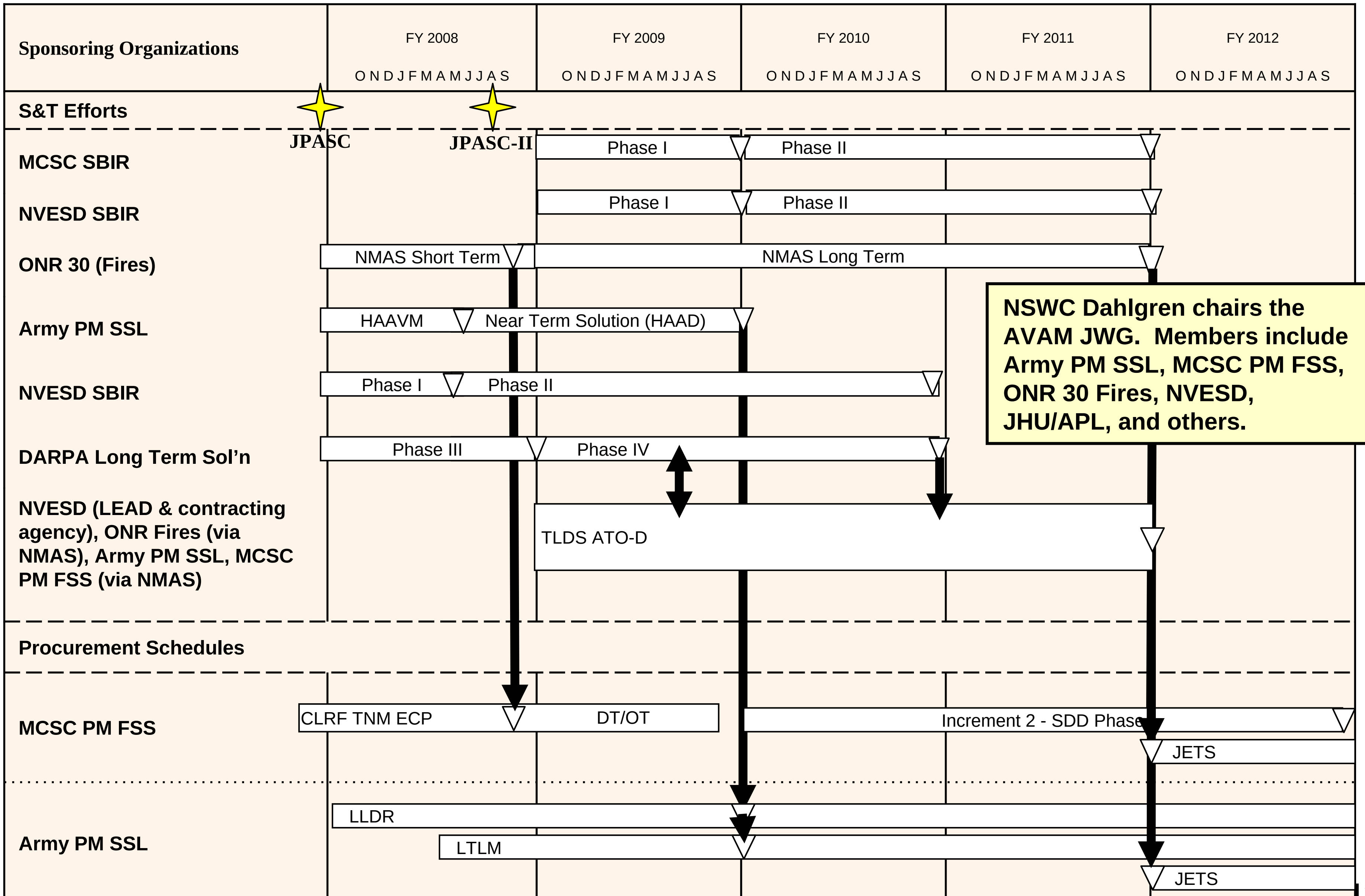
Tools

- Online tools are used to share data within the AVAM JWG
- All government support contractors must have appropriate, active Non-Disclosure Agreements on file



AVAM JWG meetings are scheduled using the Discussion & JWG Announcements page. Notification can be sent to all members when items are posted, simplifying the scheduling process.

Joint Development Efforts for AVAM



DISTRIBUTION STATEMENT A

FY09 Alternatives Analysis

Approach	Perf. < 4 mil (T)	Size < 50 in^3	Weight < 2 lb	Power < 5 W	Cost < 20 K	Maturity FY09
GPS						
Ring Laser Gyro						
Fiber Optic Gyro						
Hemispherical Resonator Gyro						
Fluid Based Gyro						
MEMS						
Celestial	requires unobstructed view of the sky					

Low Risk

Medium Risk

High Risk

Summary

- All services currently have the capability to very precisely miss targets
- All services require small, lightweight, precise azimuth sensor unaffected by the environment
- Joint development efforts are capitalizing on DoD investment to develop suitable azimuth sensors

CTA INTERNATIONAL

CTAS Maturity Briefing

9th April 2009

David Leslie, Chairman CTAI

CTA INTERNATIONAL

BAE Systems' medium calibre capabilities

- Designs and manufactures medium calibre weapons and ammunition
- Both buys and sells medium calibre systems
- Has unique global capabilities and knowledge in the medium calibre domain

MTIP & MTIP2

Toutatis (Remote Turret)

40mm Cased Telescoped (40CT)

CV90 30mm

CVR(T) 30mm

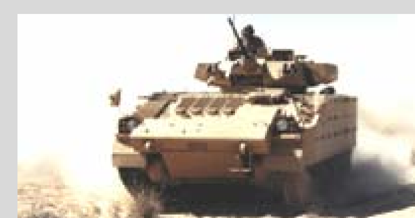
CV90 35mm

Warrior 30mm

20mm - 40mm

Bradley 25mm

CV90 40mm (Bofors)



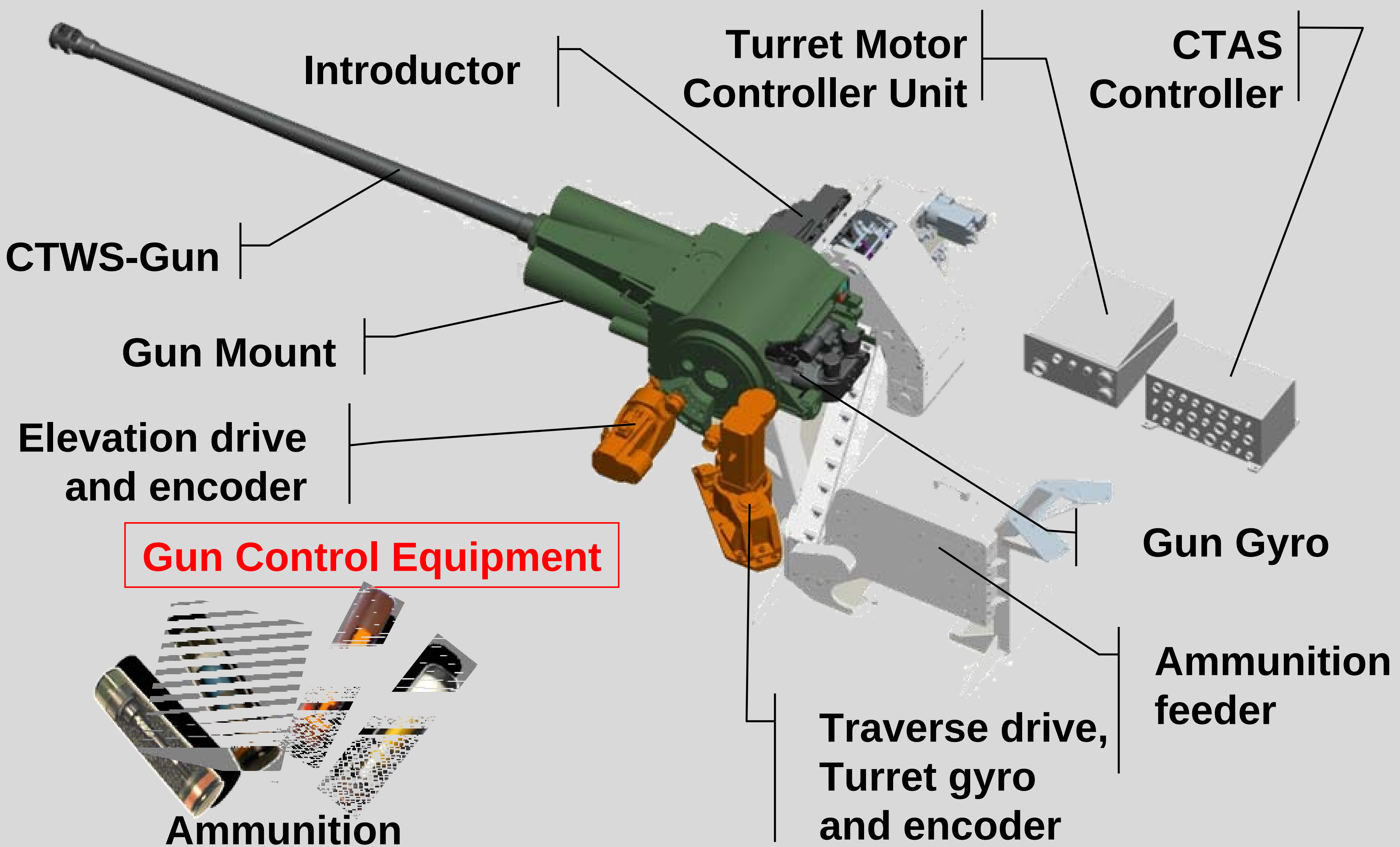
Warrior 25mm

The JV Company

- CTAI - private joint venture (JV) company 50/50 BAE Systems and Nexter Systems
- Dedicated Anglo-French team, focused on 40mm Cased Telescoped Armament System (CTAS)
- All UK and French staff are based in Bourges, France

CTA INTERNATIONAL

40 Cased Telescoped Armament System (CTAS)



CTA INTERNATIONAL

CTAS background

- 1994 **CTAI created by Giat and Royal Ordnance**

  (First activities around 45mm CT)

- 1997 **40mm selected; CTAI scope of work is CTAS**

  (40CT Gun + Ammo + Ammo handling system)

- 1999 **MoD OA study output shared with US DoD;**

  First integration into turrets

  (Bradley IFV + US-UK Tracer/Scout programme)

- 2002 **MoD & DGA OA studies;**

  MoD & DGA risk reduction contract

- 2004 **MoD & DGA contracts to integrate 40CT into turrets**

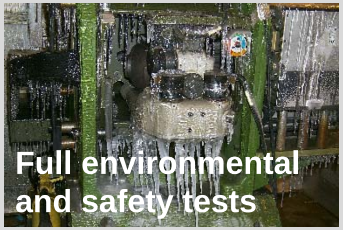
  (MTIP & unmanned turret TOUTATIS)

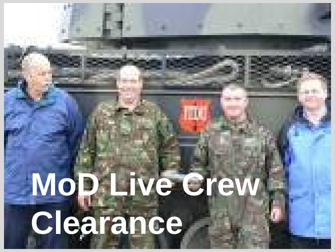
- 2005 **Extended scope of JV agreement to CTAS**

  (40CT+Ammo+AHS+Gun Control Equipment + ballistics control)

- 2008 **Downselected by MoD after additional independent OA**

  (mandated item for Warrior and FRES-Scout programmes)



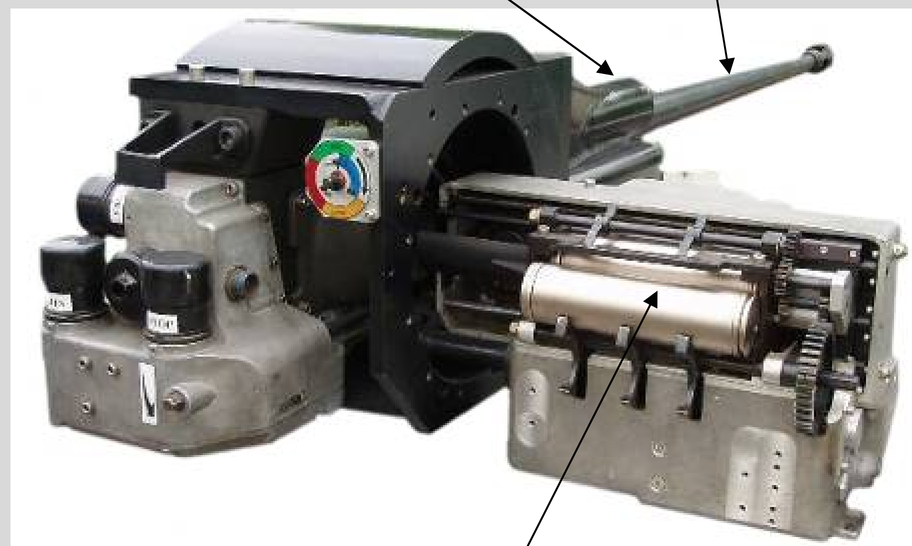


CT Technology background (gun and feeder)

- Rounds introduced through rotating breach

Mechanical recoil system

70-calibre barrel with muzzle brake

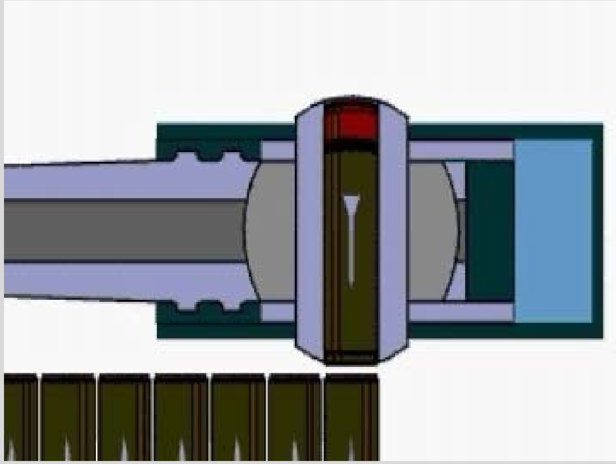


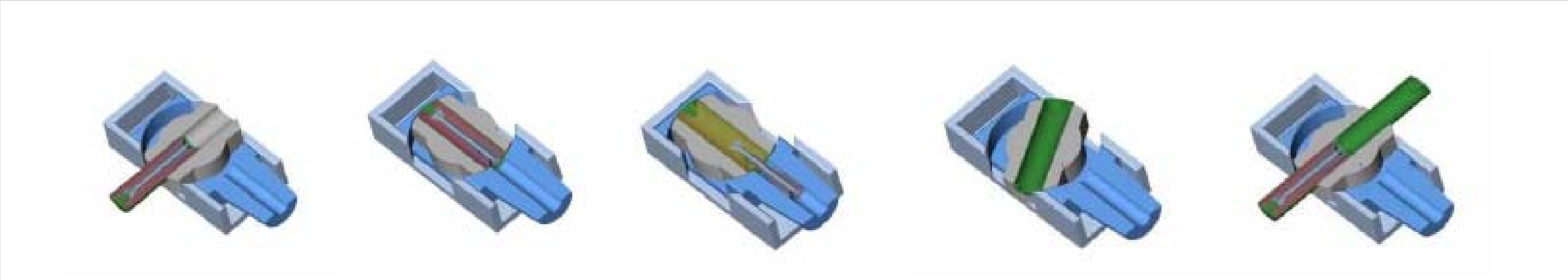
Rotating Breech

Ammunition in introductor

CT Technology background (gun and feeder)

- "Push-through" concept
- Commercial "Gear box" technology
- High reliability





1. Ammunition enters the rotating breech

2. breech revolves thru 90° to align with barrel

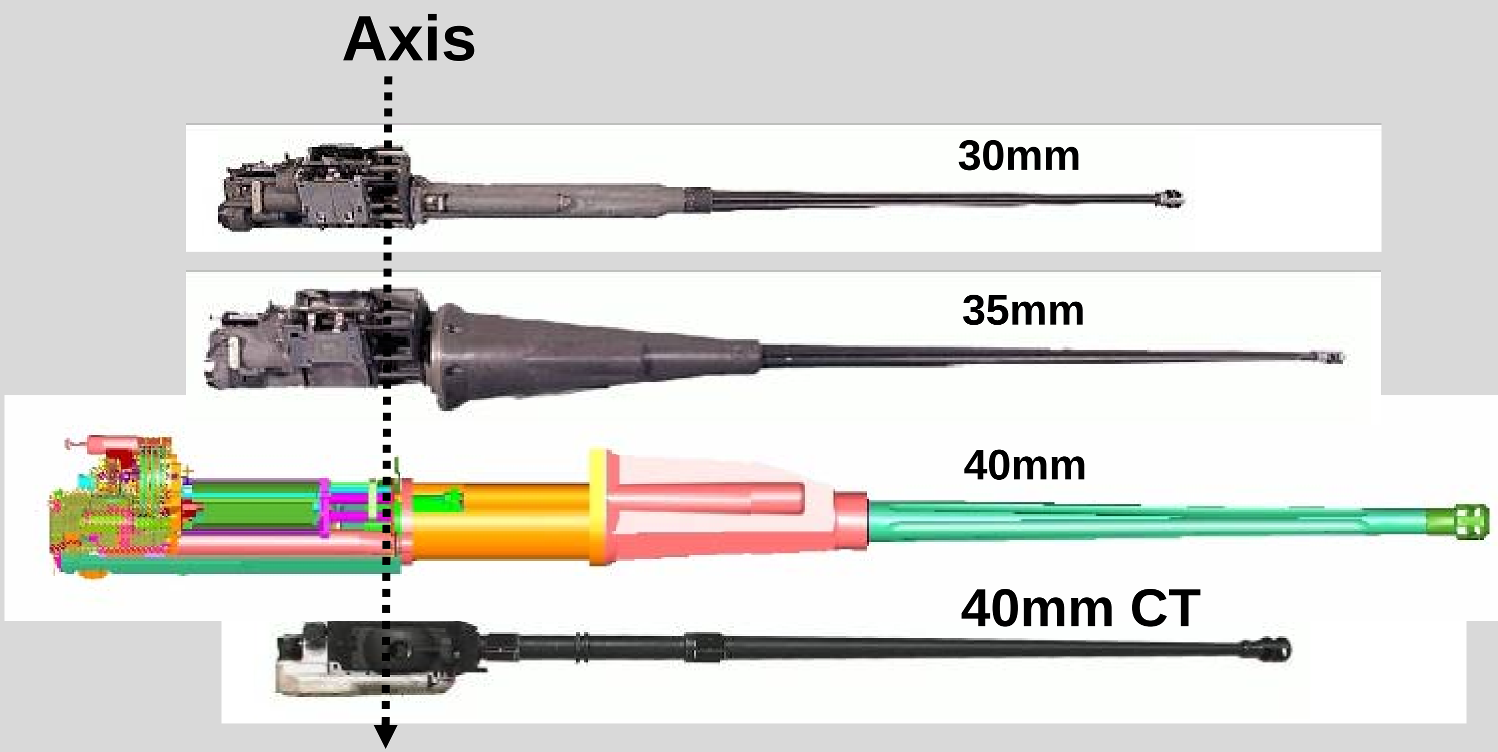
3.
• Round is fired
• the breech recoils
• the projectile leaves the barrel

4. breech revolves another 90°

5. Empty case is pushed out by the next round

CT Technology background (gun and feeder)

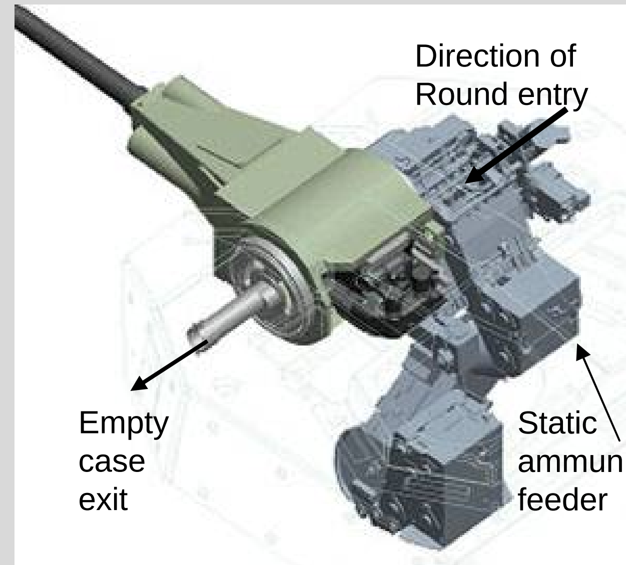
- Minimal intrusion to the crew compartment compared to conventional weapon systems

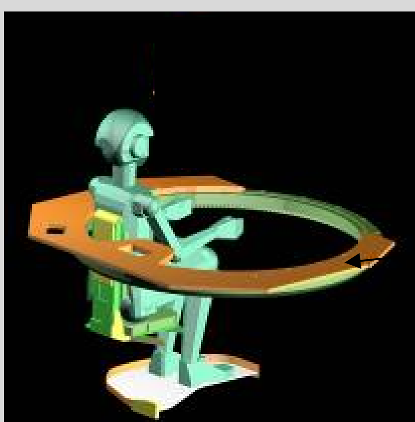


Source: Janes

CT Technology background (gun and feeder)

- Axis of introduction along the trunnion axis
    - minimizes gun intrusion
- Static ammunition feeder
    - minimizes swept volume
- Out-of-balance managed by high-performance GCE



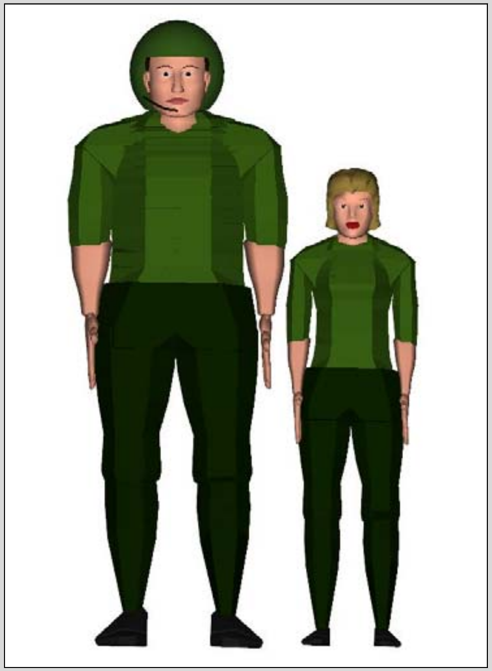


Maximises use of limited turret basket volume and an extreme 1.4m turret ring diameter

CT Technology background (gun and feeder)

• CTAS positioned well forward of the Commander and Gunner

• allows the turret crew to concentrate on their core tasks (IFV or Scout)


illustrative

designed to accommodate:

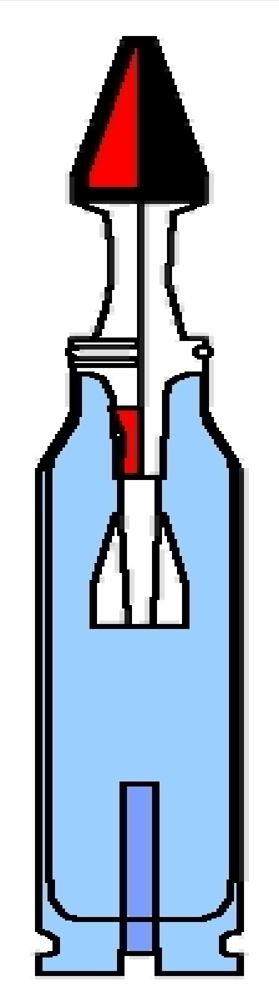
- 2x 95th percentile men
- or 2x 5th percentile women
- in full body armour and helmet

CT Technology background (ammunition)

• Unlike conventional rounds, the projectile is ‘telescoped’ within the cartridge case and surrounded by propellant

• The cartridge case diameter increases to provide efficient internal volume

• CT is 30% more volumetrically efficient than conventional ammunition



CT Technology background (ammunition)

- Two ammunition natures to achieve four effects
- 40mm offers significant Operational benefits
- UK MoD Operational Analysis of 40mm CT (Unclassified quotes from UK MoD)

"…clear advantage in urban Operations…increases platform survivability…"

Defeat of RHA and add-on special armours

Point Detonating defeat of structures with behind-structure effect

Airburst suppression, both 'line of sight' & 'non line of sight' land and air targets

Defeat of soft skin targets

$\underbrace{\hspace{3cm}}$

'APFSDS' ammunition

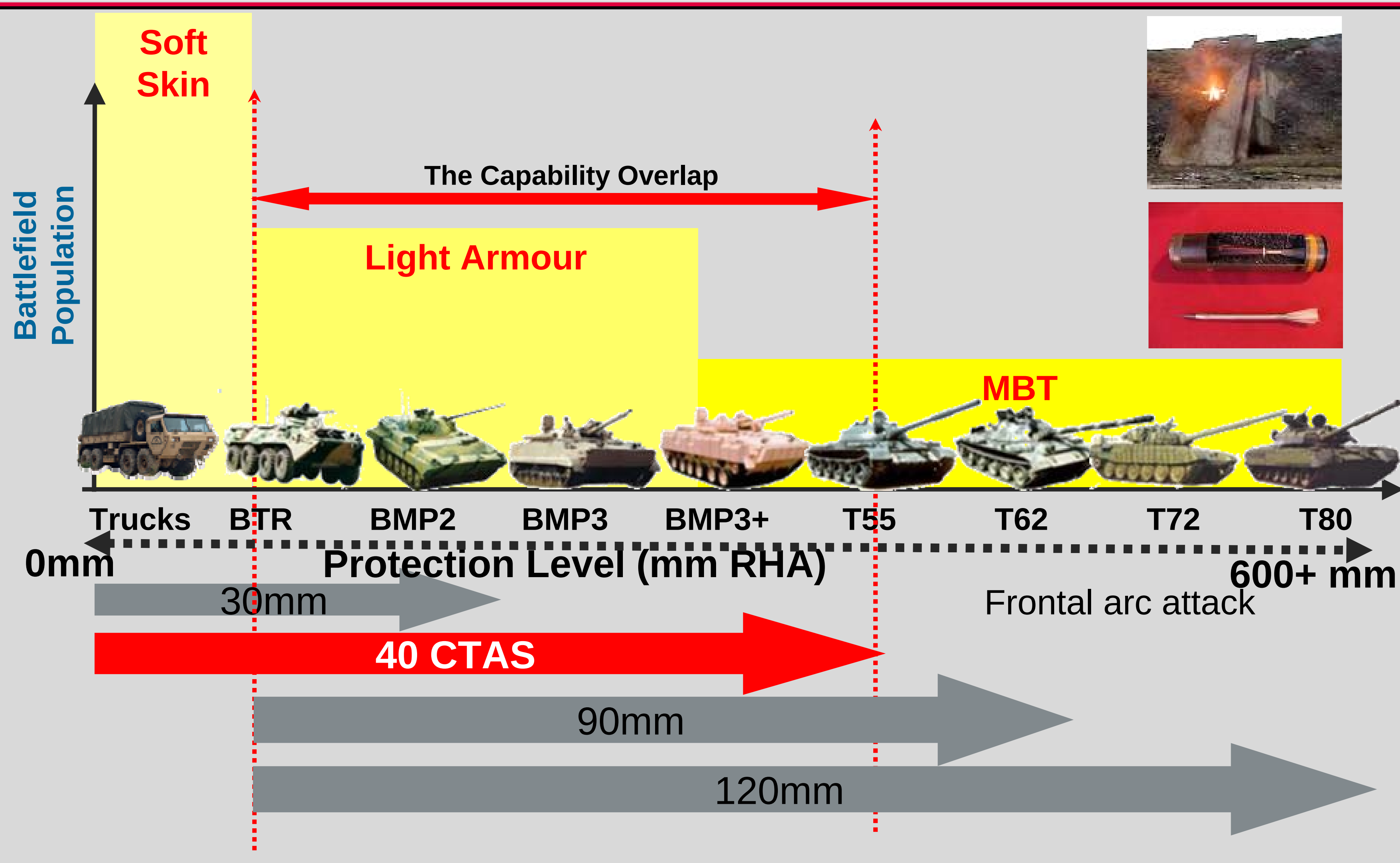
$\underbrace{\hspace{9cm}}$

'GPR' ammunition

i.e. Point Detonating + Air Burst fuzed HE ammunition <u>combined</u> in one general purpose round (GPR)

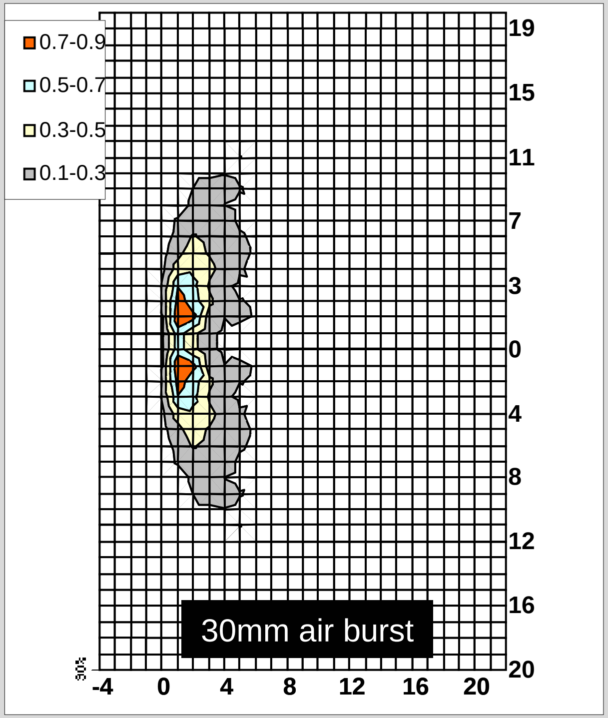
CTA INTERNATIONAL

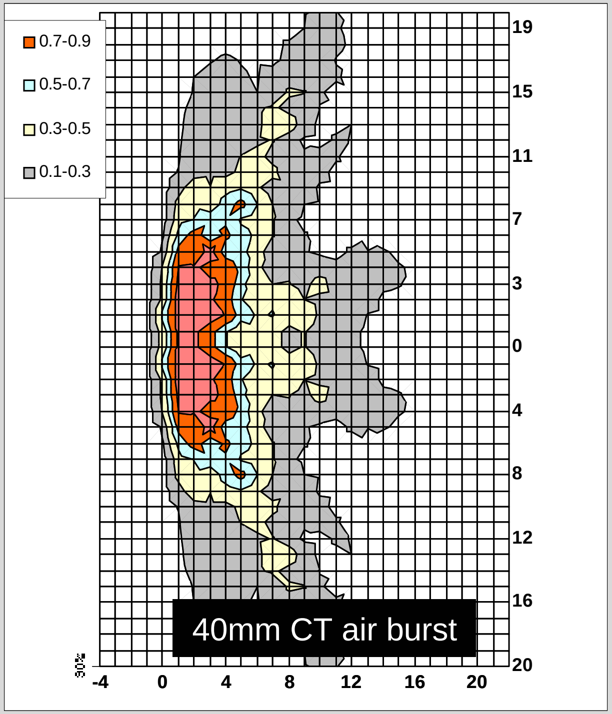
CT Technology background (ammunition: APFSDS)

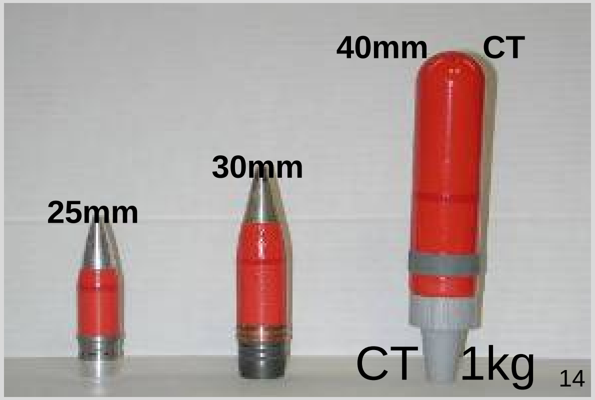


CT Technology background (ammunition: GPR)

- 40mm General purpose round (GPR) ; one round type
- Air burst and point detonation functions combined
  - Air Burst for suppression tasks
  - Point Detonating for buildings (STANAG 4536) and defensive positions







CTA INTERNATIONAL

General Purpose Round – Point detonating urban ops

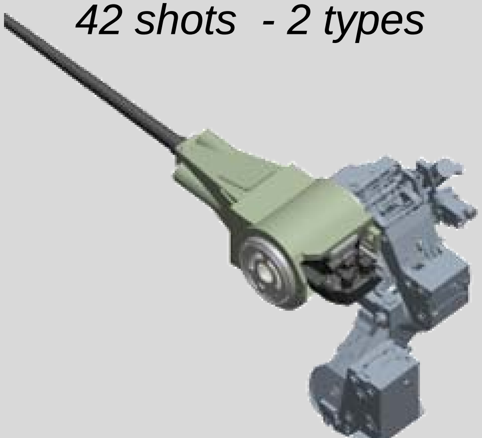
- Breaches concrete walls with behind-structure effects
- 210mm steel-reinforced concrete (STANAG 4536)

General Purpose Round – Air Burst suppression tasks

Turret Integration

- Ammunition handling systems adaptable to user requirements and turret design
- Sustainable reloading

MTIP
42 shots - 2 types

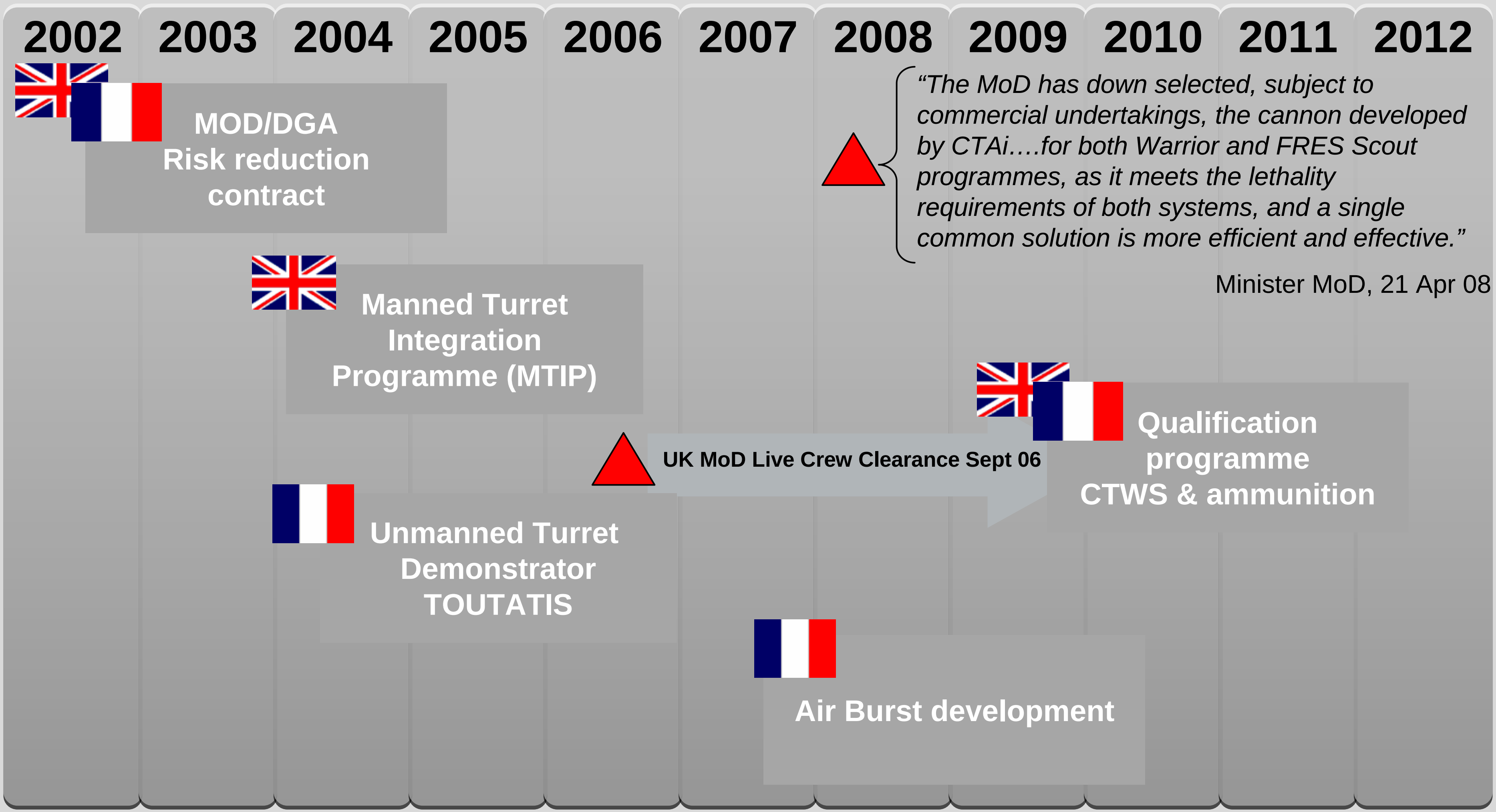


VBCI
70 shots - 2 types

Toutatis
52 shots - 3+ types
(Remote turret)

CTA INTERNATIONAL

UK MoD and French DGA Cooperation



Output shared between UK MoD and FR DGA

UK MoD and French DGA programmes

Manned Turret
MTIP

Objective Future Cannon Programme (OFCP)

Unmanned Turret
Toutatis

WARRIOR

FRES Scout

AMX 10 RC
VBCI

EBRC

Industrialisation

- Industrialisation process started 2006 in UK and France after UK MoD awarded ‘Live Crew Clearance’
- First deliveries in 2010

BAE SYSTEMS

Glascoed, Wales

CTA INTERNATIONAL

Bourges, France

nexter MUNITIONS

La Chapelle, France

Summary

1. 40CT is moving from ‘development’ to ‘industrialisation’
2. 40CT offers an innovative approach to high lethality and lower integration burden
3. 40CT family of ammunition allows greater ‘utility’ from IFVs
4. FR aligning with UK for a joint launch
5. Offers a real choice to potential global customers

Questions?

RDECOM

ARL

Predicting the spin history of munitions

Michael Minnicino

U.S. ARL
Weapons and Materials Research Directorate
Materials Division

9 April 2009

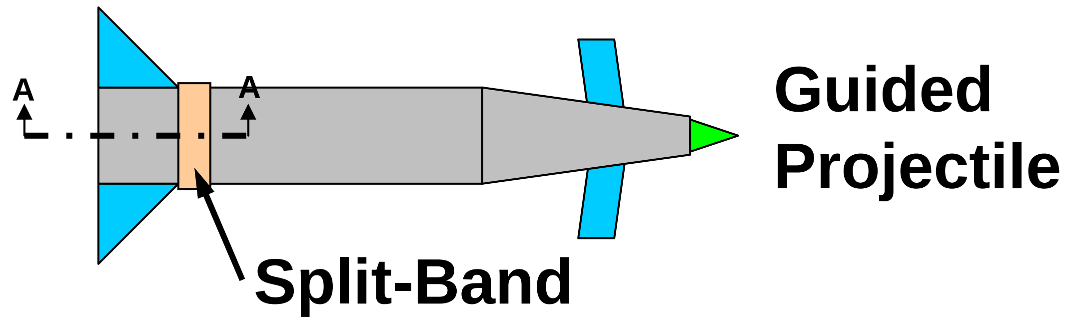
Motivation

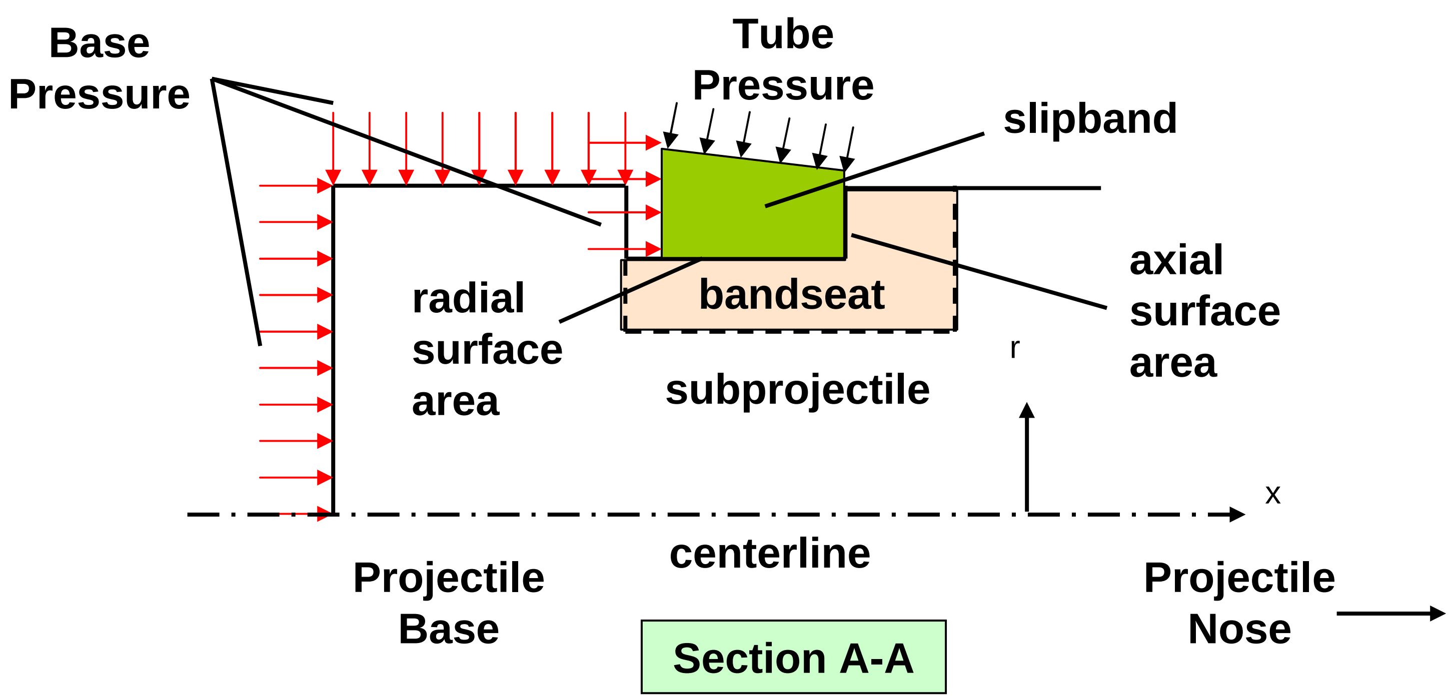
Guided munitions spin much less than conventional munitions.

Guided munitions fired from rifled cannons need to be despun.

The guided munition is uncoupled from the cannon rifling by a two-piece band (aka split-band).

Split-Band Theory and Design





Very Affordable Precision Projectile (VAPP) Program

- Weight ~ 42 lbs
- Axial MOI ~ 108 lb-in^2
- Muzzle spin rate ~15 Hz
- Gun System = M119 105 mm Howitzer (M20 Tube)

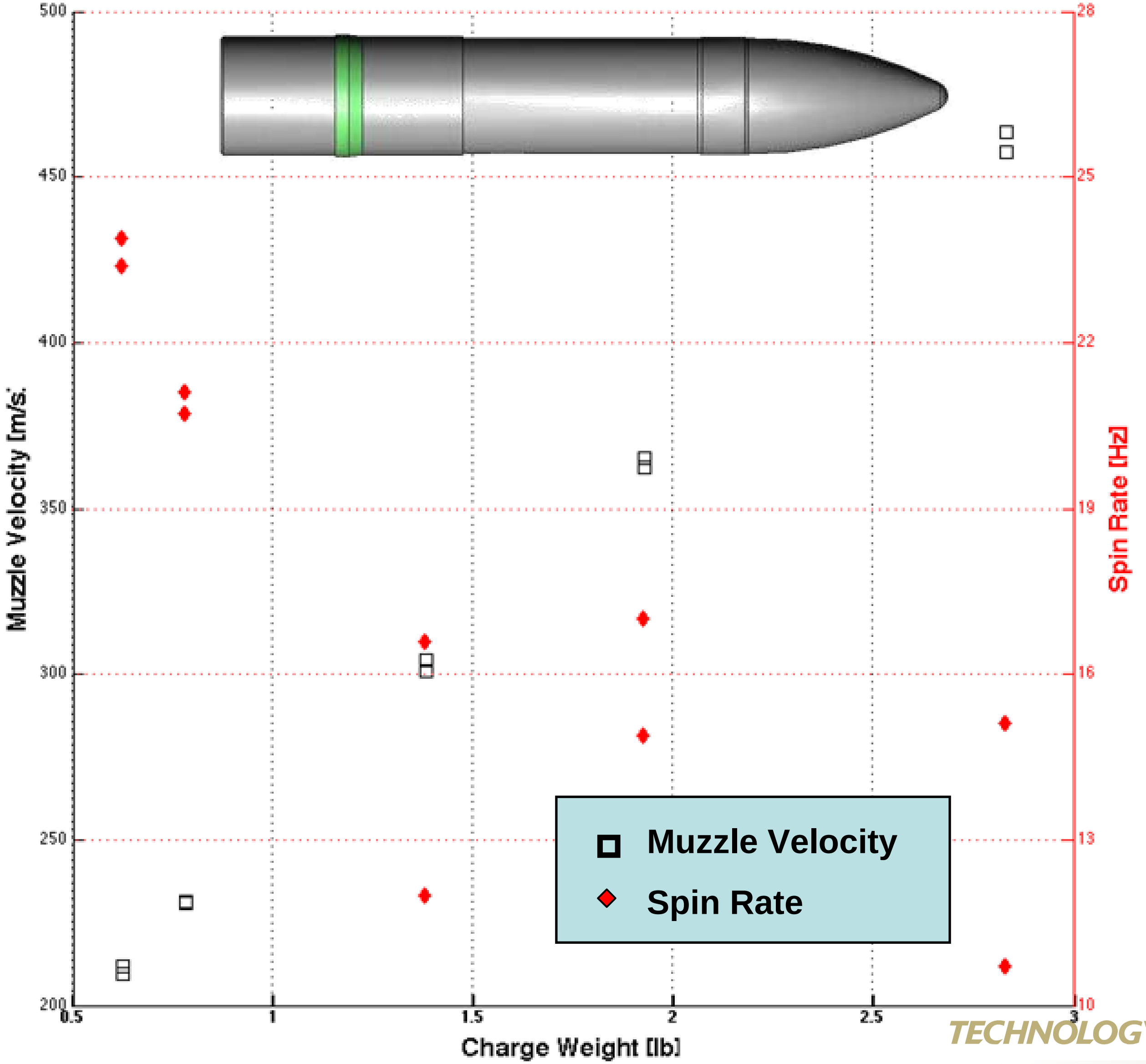
The M20 tube has a “gain-twist” rifling profile

- initial twist is 1:35 at the origin of rifling
- final twist is 1:18 near the muzzle

Twist = the number of calibers for a fully spun munition to make one revolution

Goal: Develop a split-band that results in a reduced spun projectile at all firing zones

Test Projectile Shot Results



Muzzle velocity is linear with WRT charge weight

Scatter evident in the spin rate data

Largest spin rate is ~24 Hz

“Bandslip” Prediction Software

Originally developed by SNL for constant twist gun tubes

Rewritten to enable the simulation of gain-twist gun tubes

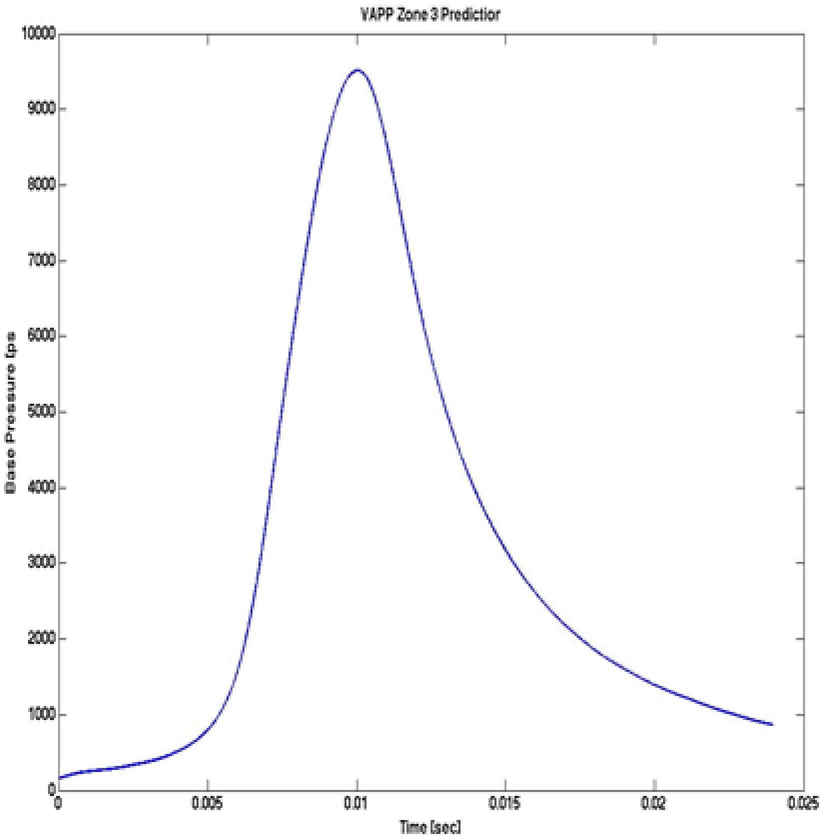
Input to software includes
•projectile inertial properties
•Split-Band geometry
•Split-Band material properties
•gun tube characteristics
•base pressure-time history
•estimate of the “tube pressure” and slipband-bandseat friction

The *slipband* angular quanities are kinematically constrained to the projectile’s linear quantities through the rifling profile

The bandseat/projectile’s angular velocity and position are calculated from first differences

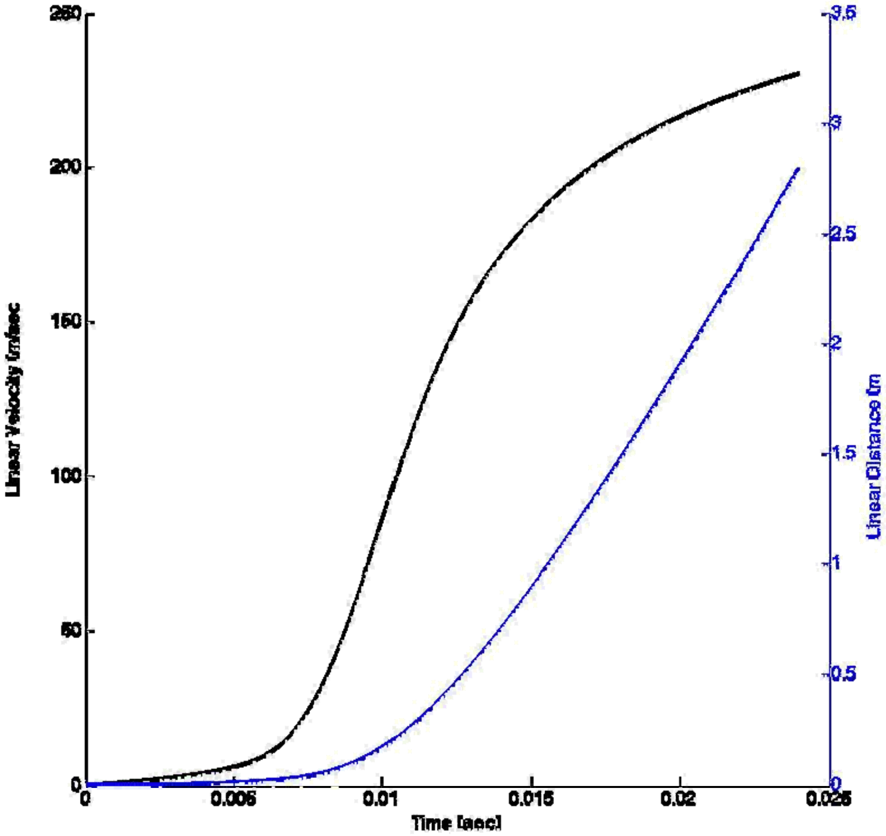
VAPP Zone 3 Simulation

Input



Zone 3 Pressure-Time Data

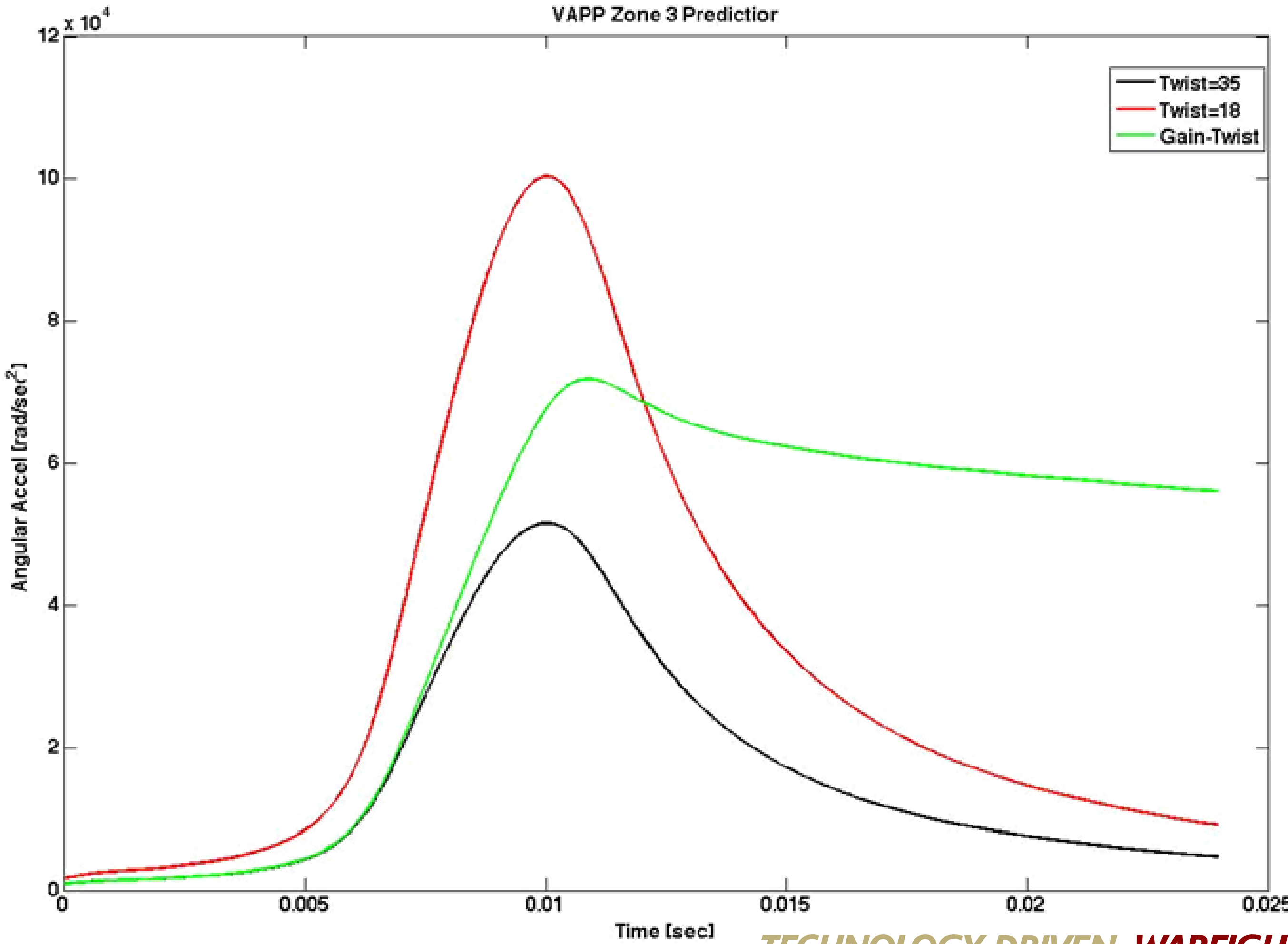
Output



Resulting linear displacement and velocity histories

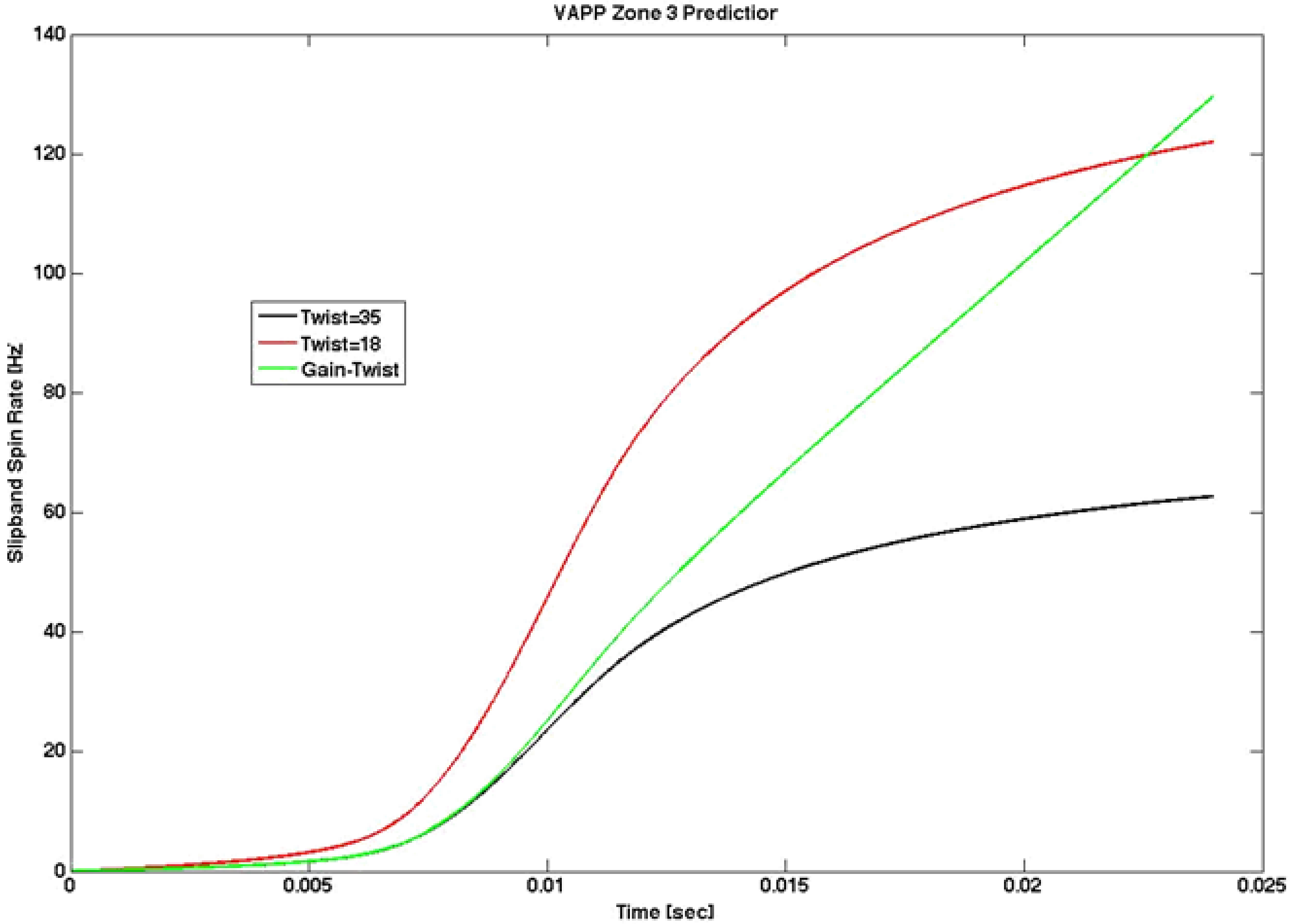
Slipband Angular Acceleration

The slipband's angular acceleration remains large due to the gain-twist rifling profile

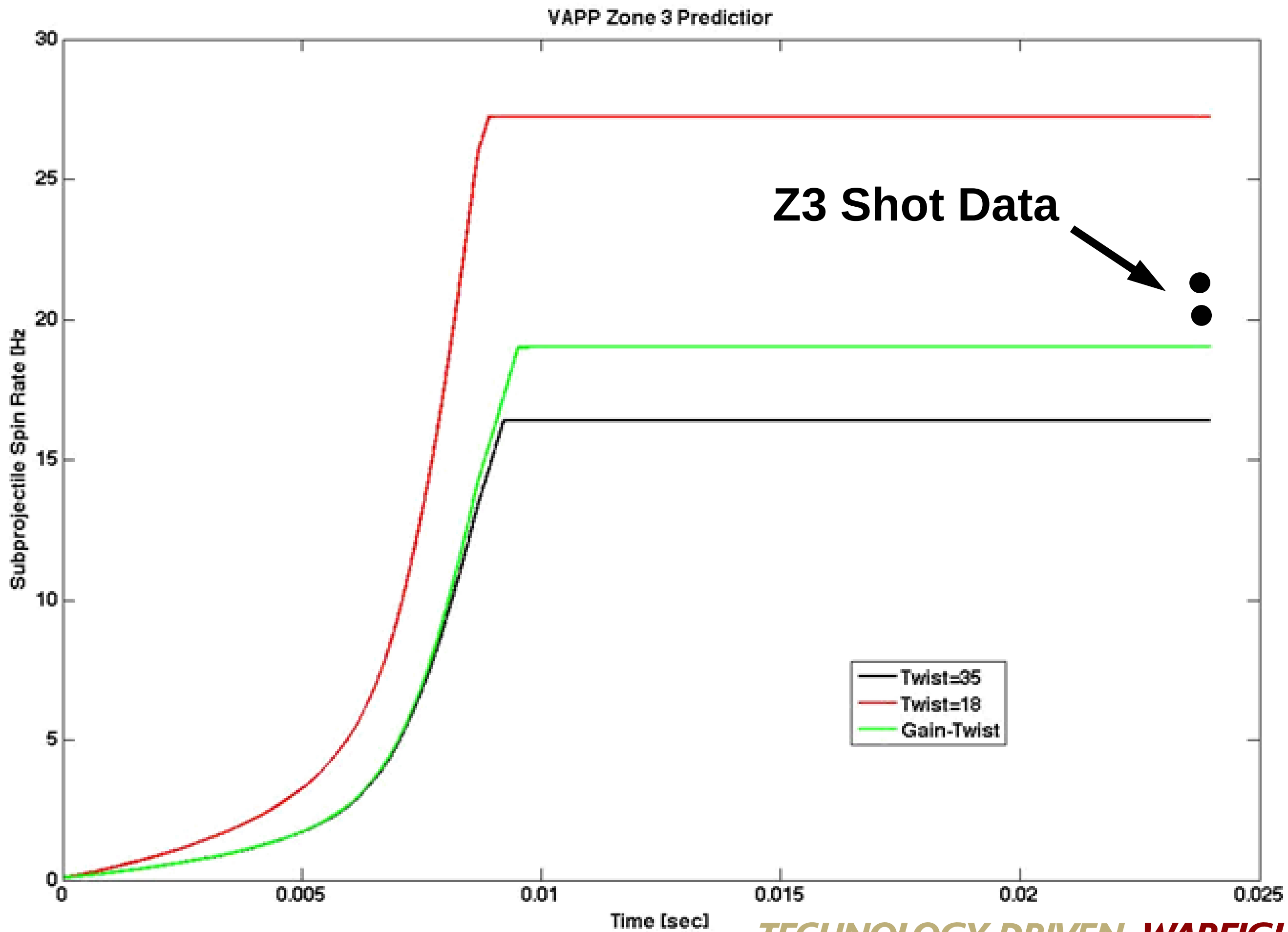


Slipband Angular Velocity

The slipband's angular spin rate $f = {}^{v}/_{(D*twist)}$



The projectile spin history depends significantly on the initial twist rate



Summary

- **Split-Band theory and design features are understood**
- **A numerical predictive capability is demonstrated**
- **A projectile spin rate of ~19 Hz (21 Hz actual) was predicted for the VAPP shot at Zone 3**
- **24 Hz was the largest spin rate recorded for the VAPP**

Questions

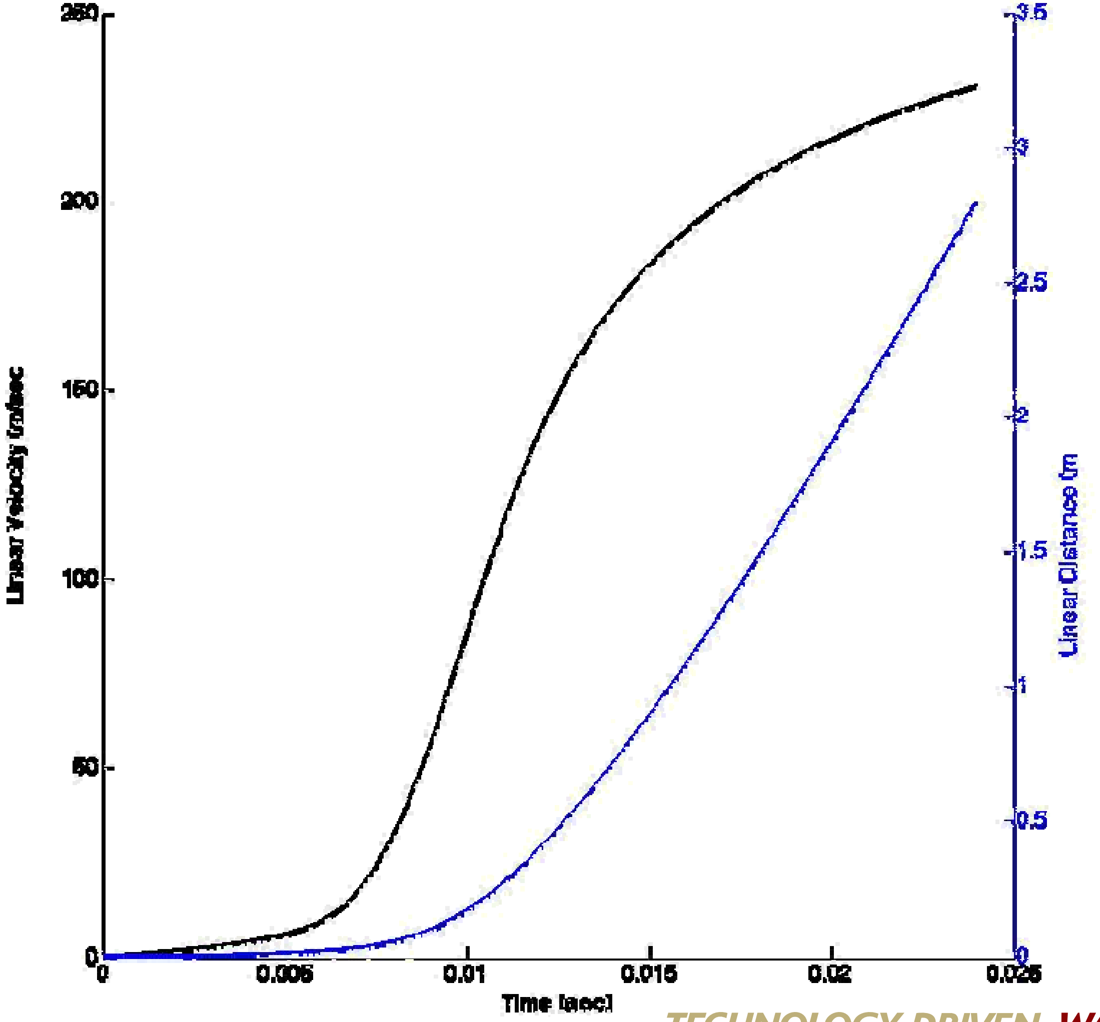
Backup Slides

More slides

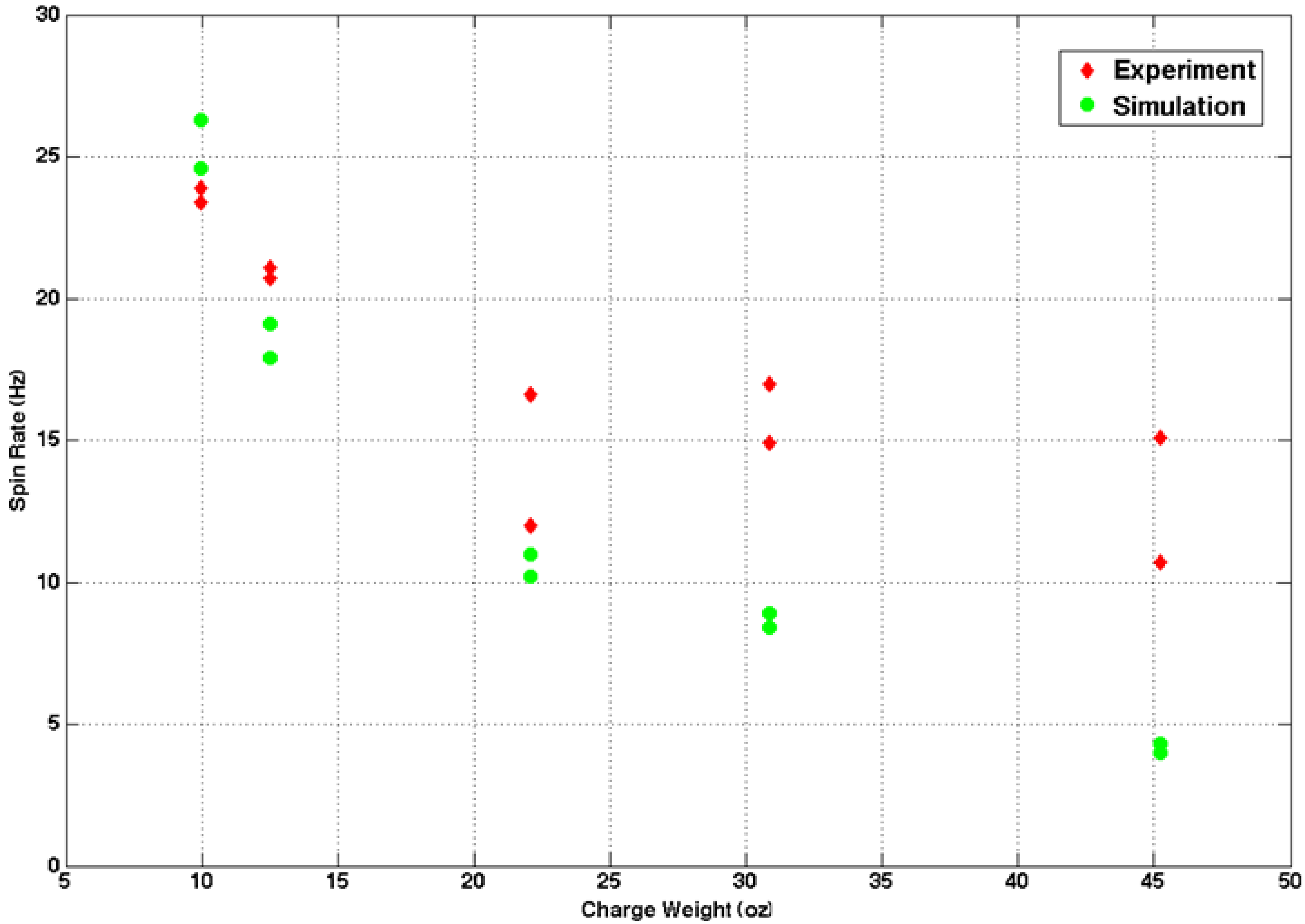
Split-Band

- **Geometry and thermal material properties are used in determining slipband behavior**
- **Base pressure and “Tube pressure are used to determine slipband “lift” time, i.e., when the base pressure is greater than the effective Tube pressure**
- **Constant twist rate is used to determine required torque needed to spin subprojectile at same rate as slipband**

Linear (Axial) Velocity and Travel



Summary


Experiment
Simulation
Spin Rate (Hz)
Charge Weight (oz)
0
5
10
15
20
25
30
35
40
45
50

A new method for fabricating copper rotating bands on munitions

Michael Minnicino
Matthew Trexler
Victor Champagne

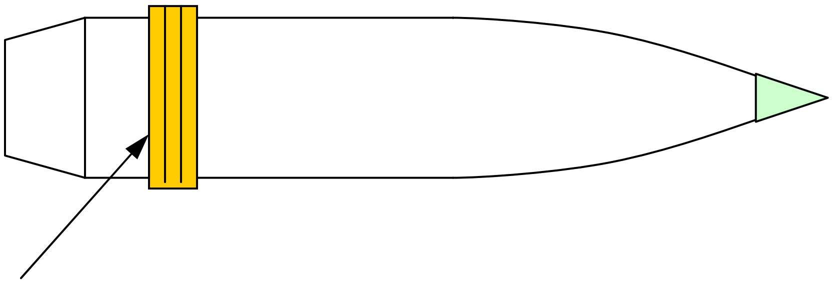
U.S. ARL
Weapons and Materials Research Directorate
Materials Division

8 April 2009

Band Types

Two Types of Bands

1. Slipband (two-piece band)
2. Rotating Band
    - Usually copper based alloy
    - Provide obturation
    - Provide torque transfer from rifling to projectile



Fabrication Methods

Traditional Fabrication Methods

1. **Weld overlay or other thermal spray process**
2. **Swage**

Non-Traditional Fabrication Methods

1. **Explosively Formed**
2. **Cold-Spray**

Motivation for Current Work

A projectile program needed a copper rotating band on an aluminum projectile component

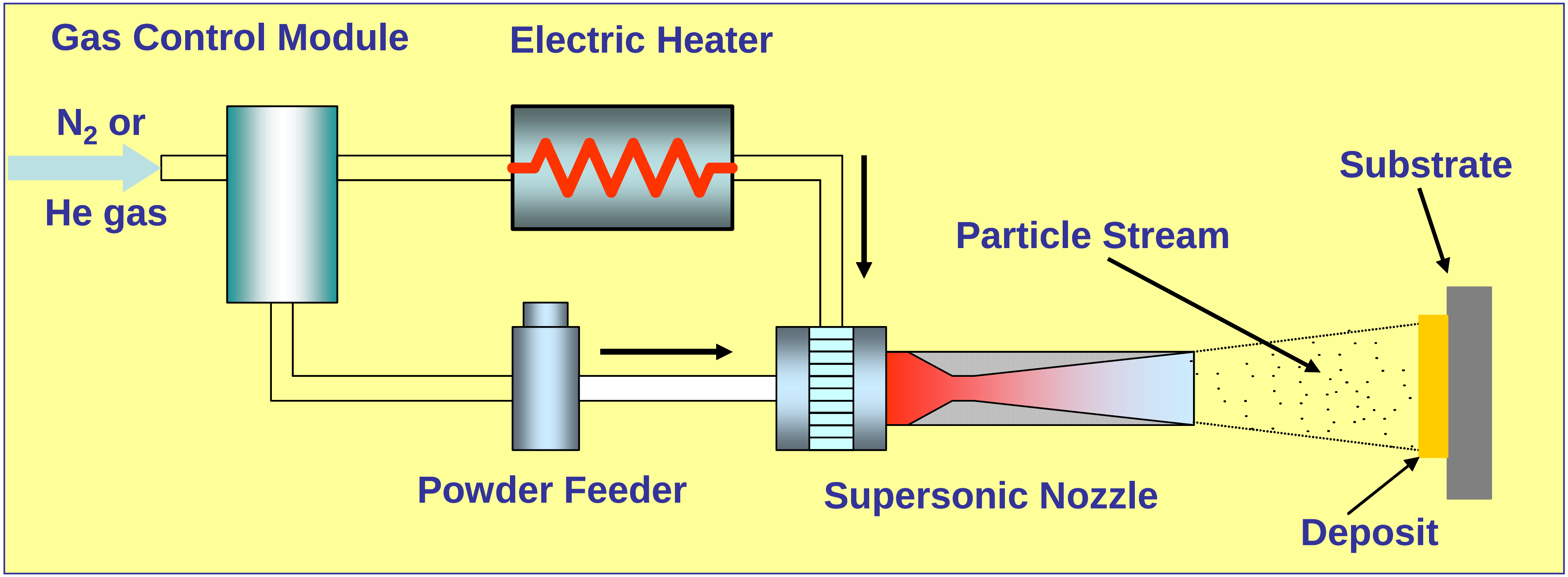
Weld Overlay – not possible

Swage – not cost efficient for R&D low volumes

Explosively Formed – not practical

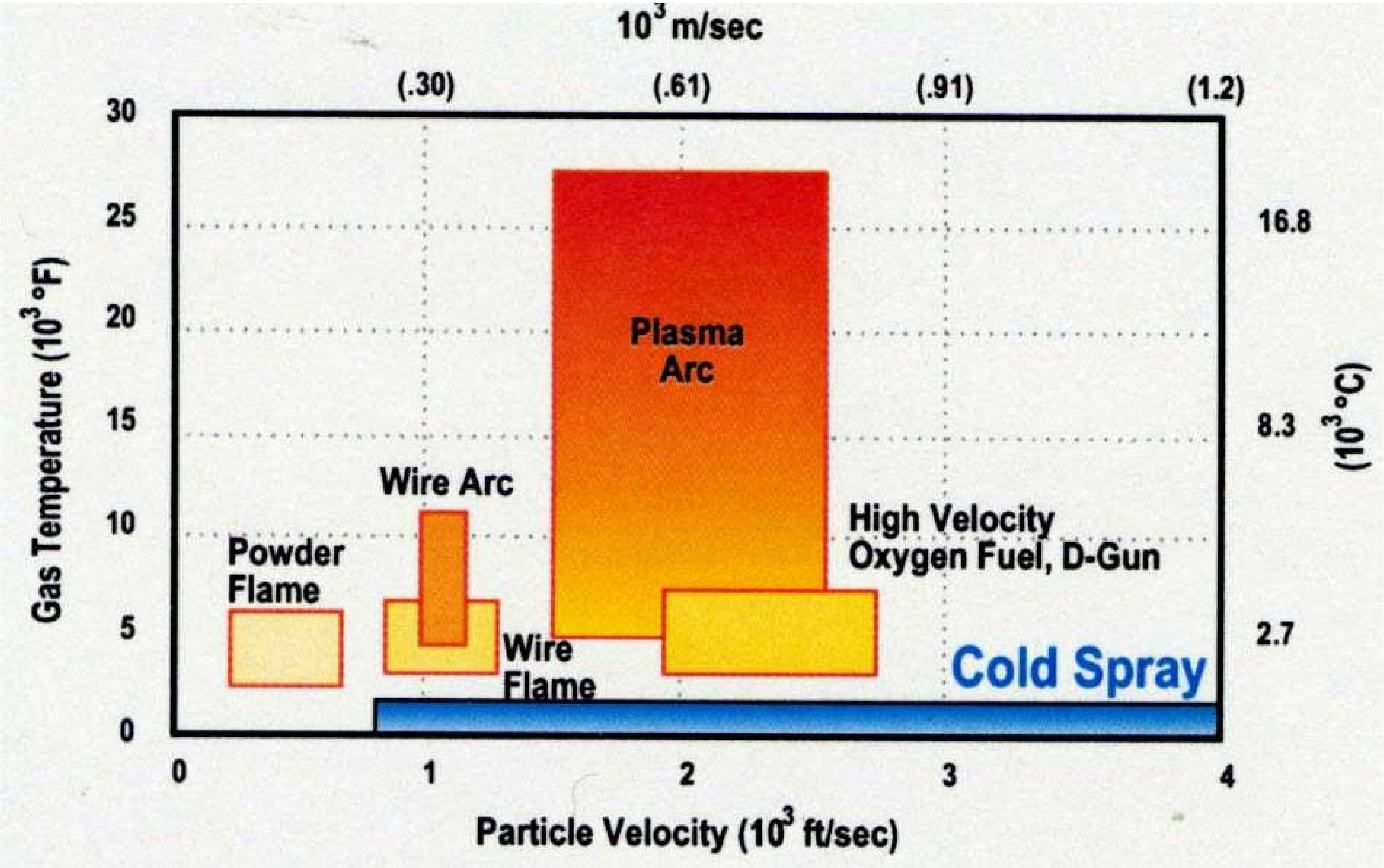
Cold Spray – quick and easy to fabricate

The cold spray process



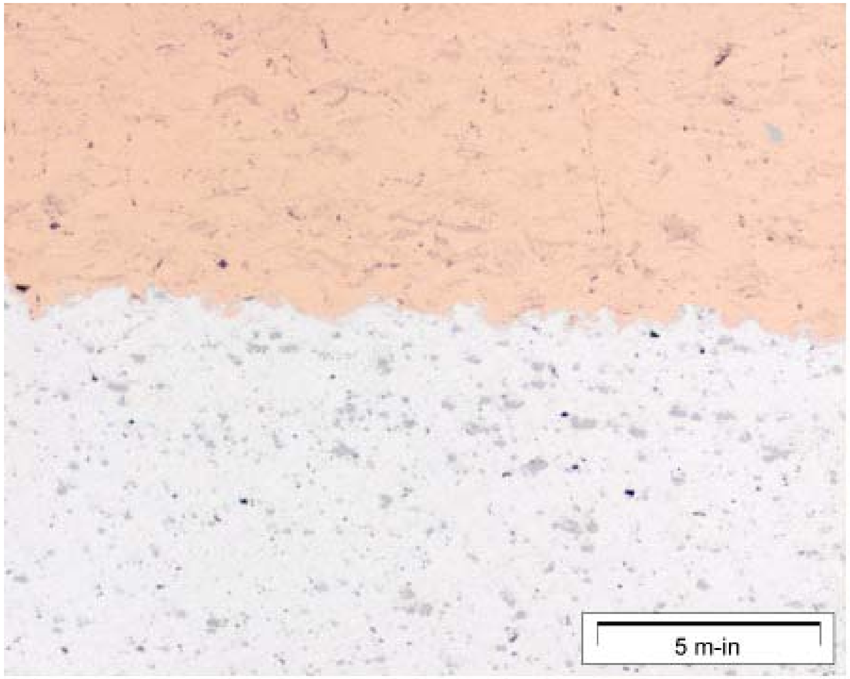
Cold spray is a process where particulates are deposited by ballistic impingement upon a substrate at super sonic velocities to form a coating or a free-standing structure.

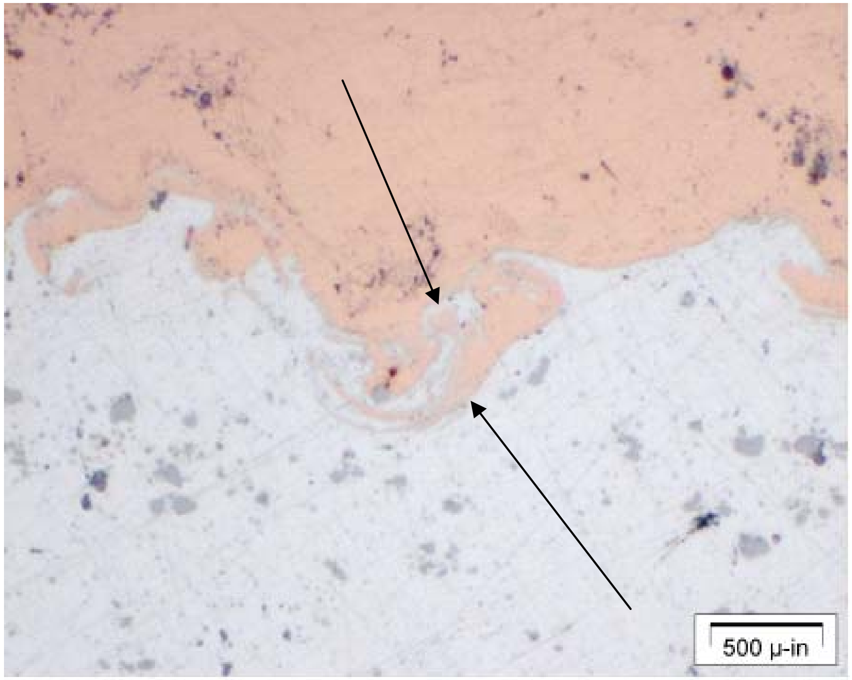
Cold Spray vs. Thermal Spray

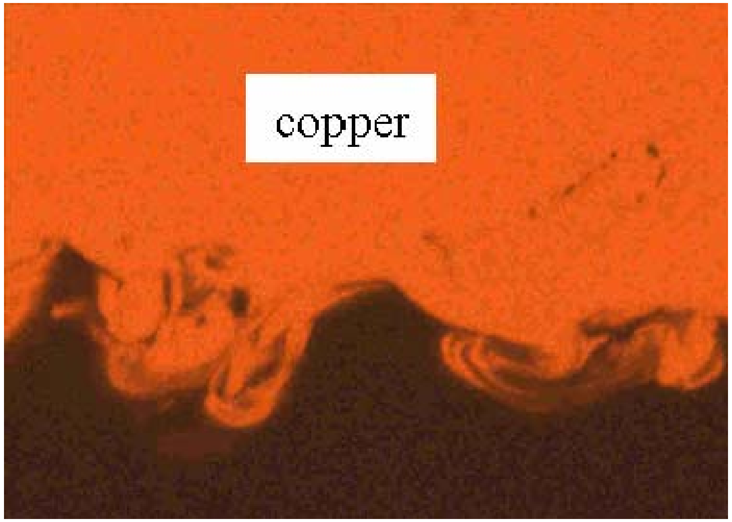


Robot-Controlled, High Pressure, He and N Gas

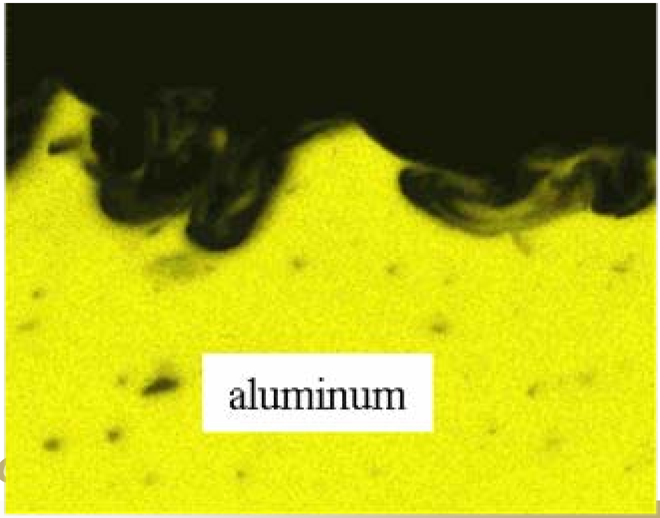
Mechanical Mixing at Interface







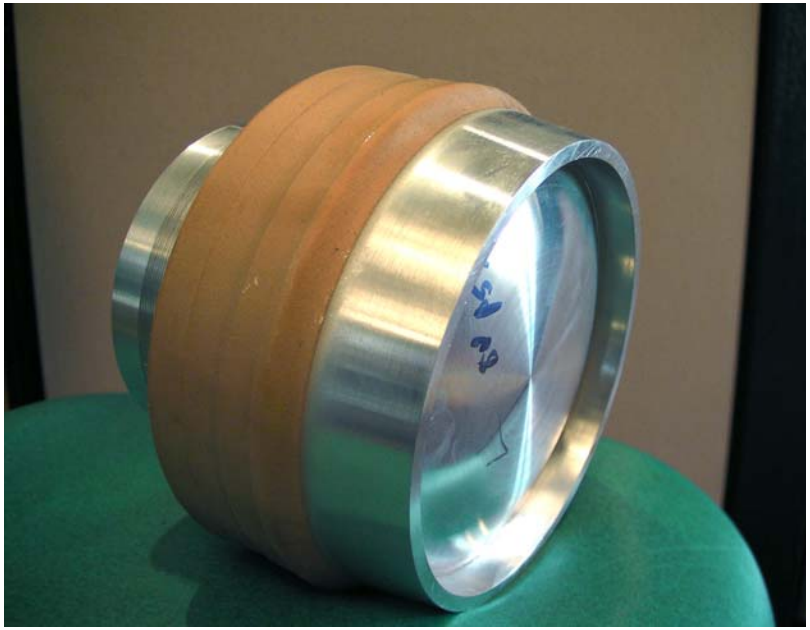
EDS X-ray Mapping showing mechanical mixing between coating material and substrate



Cold Spray Band Fabrication

Before application of cold sprayed copper band

After application of cold sprayed copper band



Bulk deposited material

The rotating band profile is machined from the bulk deposited material

Rotating Band

Test Projectile

1st Demonstration

Recovered Test Projectile

One of four test projectiles fired for 1st Demonstration

Test projectiles fired at M4A2-Zone 3(x2), 4, and 6

Engraved Cold Sprayed Copper Band

Spall Failure

Issues

The only identified issue is the spall of the copper rotating band at muzzle exit (2 instances)

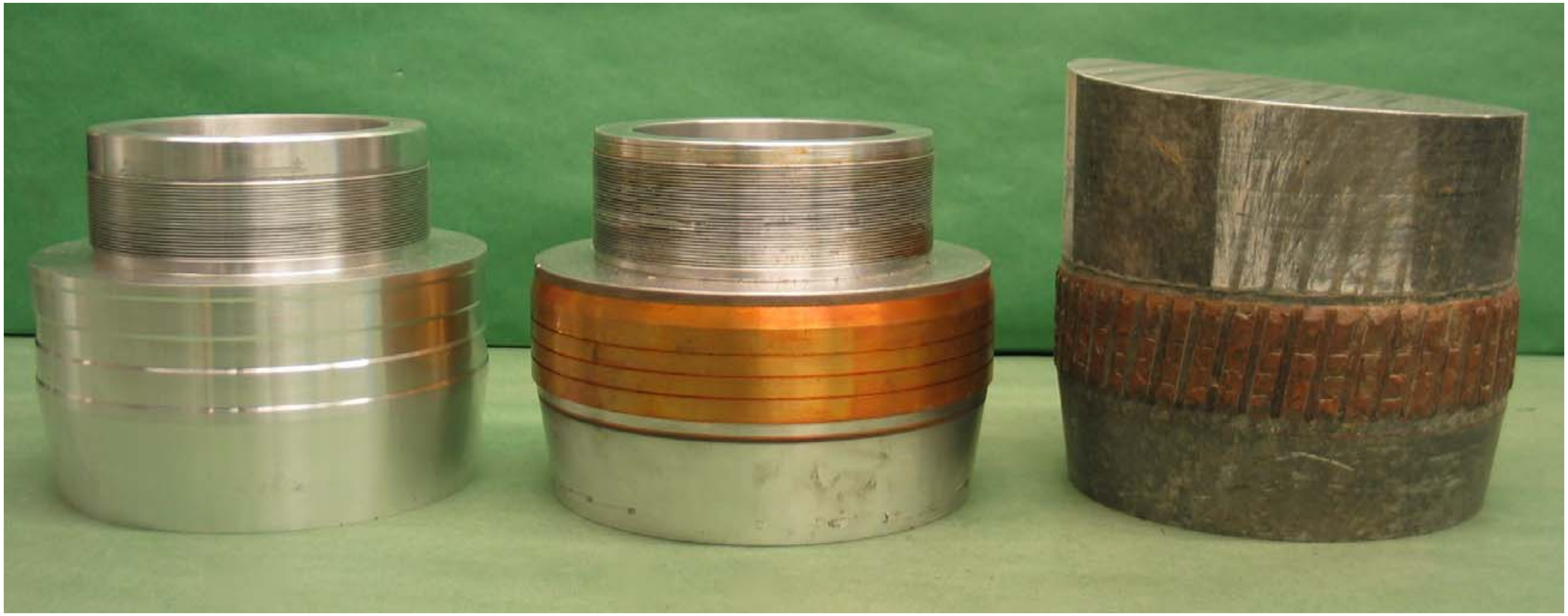
Issue can be overcome by changing the cold spray process parameters to improve spall strength

- **Particle material (single vs. multi-material powders)**
- **Gas temperature**
- **Particle velocity**
- **Particle size**

Advantages of Cold Spray

- High deposition rates
- Deposition efficiency greater than 70%
- Low residual stress
- Porosity less than 1%
- Low temperature deposition
- Solid state bonding
- High density, low oxide content
- Young’s modulus 85% of bulk material
- Compressive residual stress
- Produces free-standing structures

Cold sprayed copper rotating bands have been successfully demonstrated on four aluminum 155 mm projectiles



Questions

25mm Ammunition Development

From idea to prototype

Martin van de Voorde (TNO)
Eelko van Meerten (RWMS)

RHEINMETALL DEFENCE

TNO

Contents

- History
- Proposal for 25 mm ammunition development
- Pre-Feasibility study for conceptual design
- Trials with conceptual design
- Conclusions → input for prototype

History

- JSF development traject
  - NL partnering in JSF-development
  - JSTAB – visit partner countries (2003)
    - Check for (new) technologies
      - Lower the costs
      - Weight reduction
    - Proposal TNO: **gun ammunition development**
      - In close co-operation with operational user and ammunition manufacturer
      - JSTAB voting (2004)
        - Ranking #1 of all ideas

TNO's proposal
25 mm gun ammunition development

Optimized Effectiveness

- Maximum firepower for 25 mm gun
- Only one ammunition type needed for air-to-air and air-to-ground combat missions

Safe

- No high explosives/detonator carried, resulting in less vulnerability of:
  - airplane itself
  - ground storage sites
  - aircraft carriers

Cost Effective

- Only one round needed for combat and training (no environmental hazards)
- Only one ammunition type gives considerable logistic advantages
- Flexible and cheap development of projectile also for possible future requirements

TNO's 25 mm proposal (2)

- Lethality optimization together with the manufacturer (RWMS) and operational user (RNLAF) to develop the best 25 mm ammunition against selected targets
  - One round for the complete range of targets: as good as an AP, better than HE
  - FAP shows good performance to complete range of targets
  - Safe solution (no explosives, no DU)
  - Cost effective solution

- TNO has unique capability to optimize frangible ammunition with respect to lethality

- JSTAB Technology Readiness level:
  - Tools and experience: 9
  - Development of 25 mm round: 6

- Proposal started in 2004
  - Prefeasibility study
  - Design and realization of conceptual model(s)

Development of 25 mm ammunition

TNO
- one ammunition type for complete range of targets
- optimal lethality
- insensitive ammunition
- reduced costs

Gun manufacturer

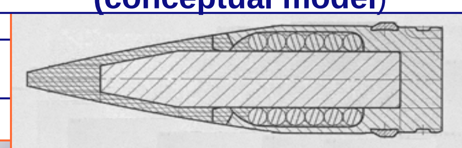
Ammunition manufacturer

Operational users

Requirements

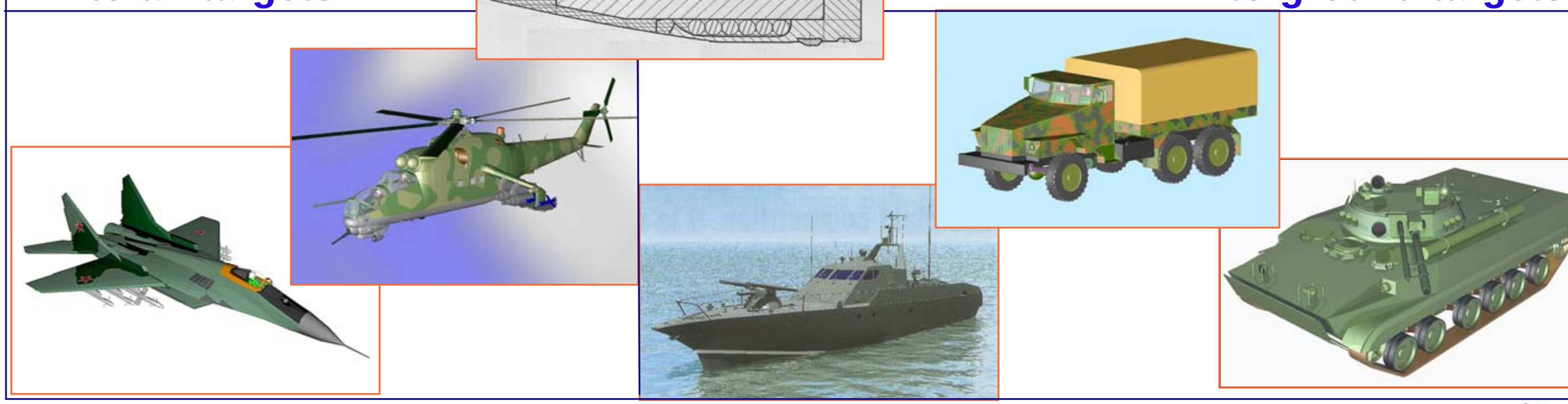
25 mm ammunition
(conceptual model)

25 mm prototype



Air-to-air targets

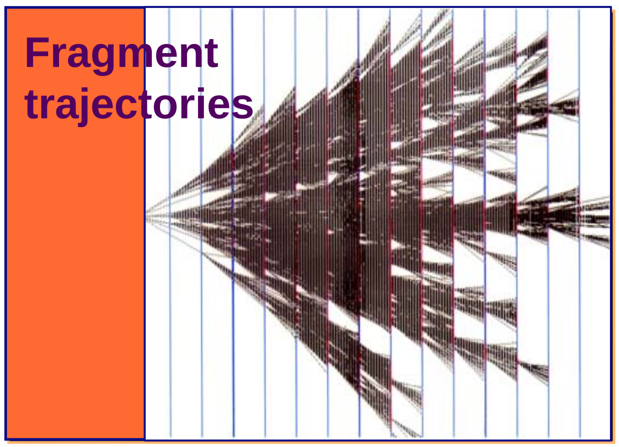
Air-to-ground targets



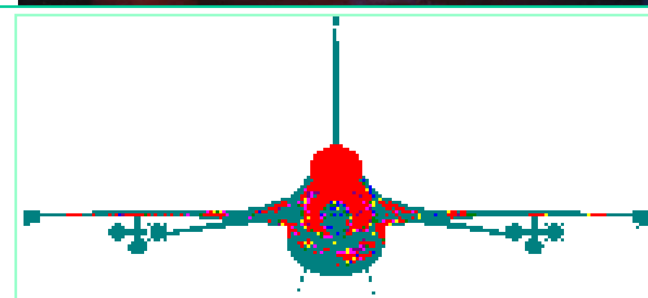
Frangible ammunition

Based on many years of experience in performing firing trials and lethality simulations against air- and ground targets, TNO has a unique capability to evaluate and develop specific ammunitions, like frangible ammunition.

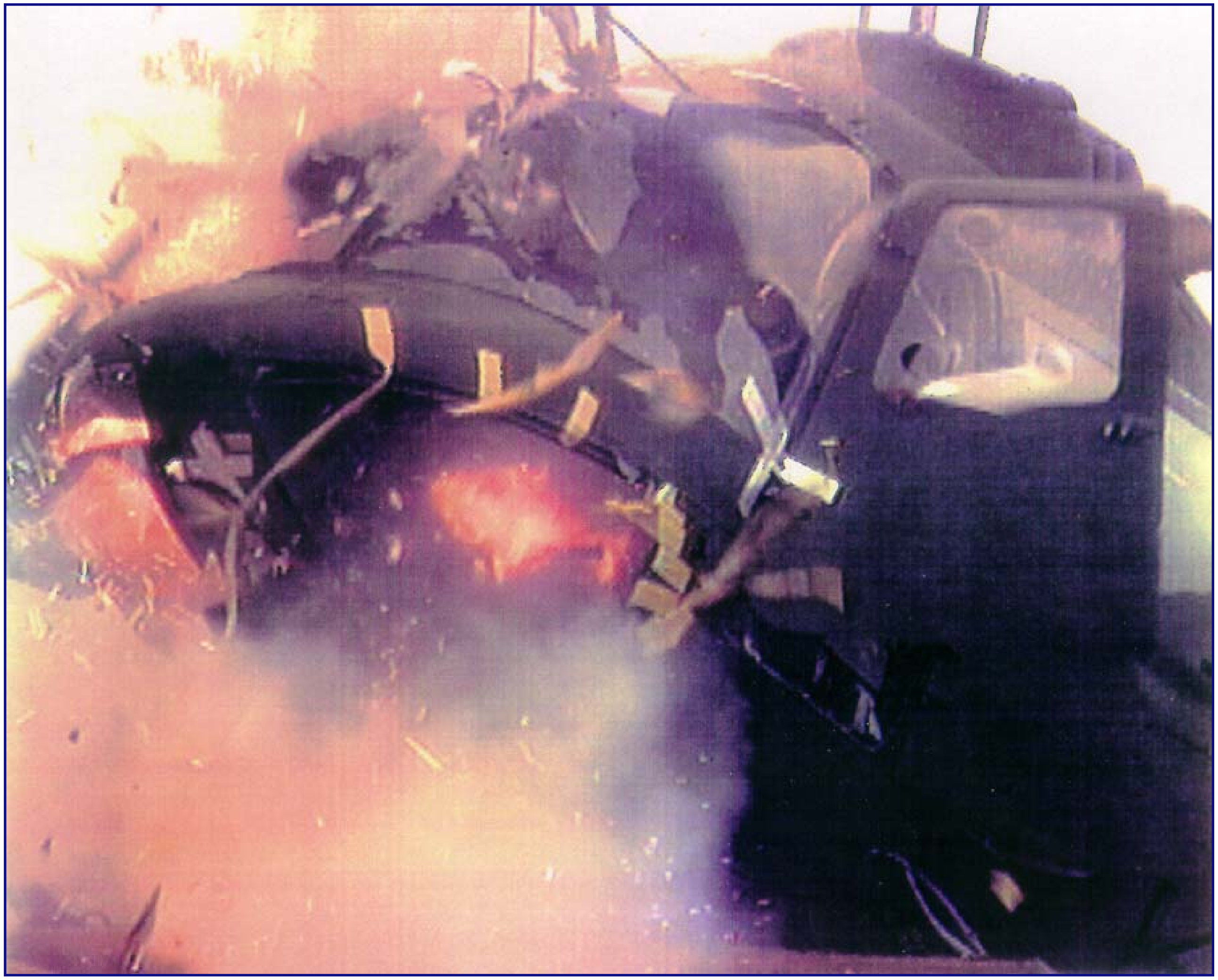
Terminal ballistics



Lethality simulations



Effects of Frangible projectiles



Experience of TNO with frangible projectiles

- TNO terminal ballistic model based on live firings against different plate arrays and combat targets:

Projectiles	Targets
• **Frangible FSP's against:** (FSP = Fragment Simulating Projectile)	**aluminum plate arrays**
• **12.7 mm FAP against:**	**aluminum plate arrays, armored steel plate arrays, urban targets, composite targets, ceramics**
• **20 mm FAP against:**	**aluminum plate arrays, armored steel plate arrays, truck**
• **25 mm FAPDS against:**	**aluminum plate arrays, armored steel plate arrays, helicopter, aircraft, IFV, urban targets**
• **27 mm FAP against:**	**aluminum plate arrays, armored steel plate arrays**
• **30 mm FAPDS against:**	**aluminum plate arrays, armored steel plate arrays**
• **30 mm FMPDS (Goalkeeper) against:**	**aluminum plate arrays, armored steel plate arrays, missiles**
• **35 mm FAPDS against:**	**aluminum plate arrays, armored steel plate arrays, composite materials, urban targets, aircraft**

Phase 1: Pre-feasibility study

- Paper study only;
  - The results are based on simulations only (no trials!!)
  - Projectile drawings/designs delivered by RWMS
  - Terminal ballistic - and lethality simulations performed by TNO
    - Based on real End-game scenario's

- TNO redesigned the projectiles by varying the penetrator mass and the number of included preformed fragments (total projectile mass constraints).

- Deliverable:
  - a paper study for preliminary 25 mm projectile designs with optimized capability in air-to-air and air-to-ground combat

Phase 2: Effectiveness optimization

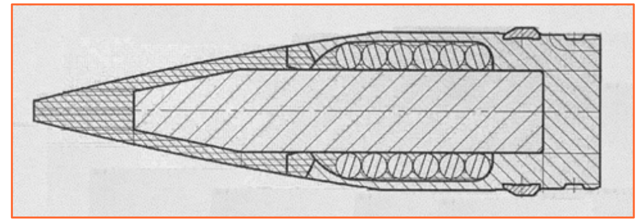
- Projectile optimization with respect to penetration and lethality
  - Penetration characteristics are determined with standard software; input data based on experiments with other caliber projectiles
  - Fragmentation characteristics are determined using TNO's Frangible Terminal Ballistic model:
    - ¤ makes fast, flexible, cheap projectile design changes possible
  - Simulation results have to be verified with trials is next step

- Air-to-ground:
  - aircraft velocities
  - dive angles
  - range

- Air-to-air:
  - Hind: air-to-ground scenario's are used
  - MiG-29

Optimisation of conceptual design (I)

- Basic concept: frangible penetrator
  preformed fragments



<u>FAP basic design was evaluated in Lockheed Martin 25mm trade study</u>

Results:
"If the partner countries want a general purpose round - this round is recommended against Air-to-Air and/or Air-to-Ground targets"

preformed fragments

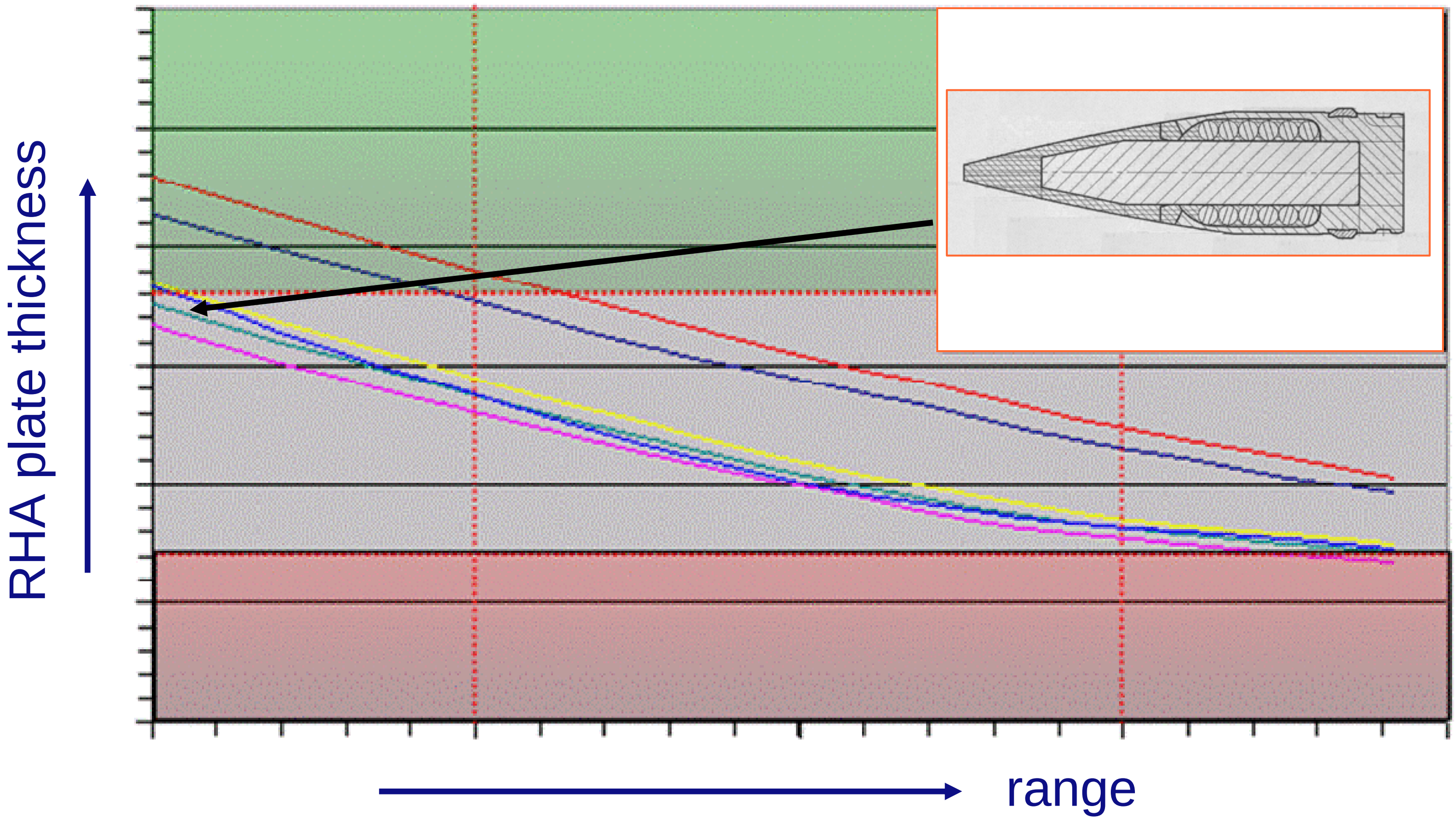
- Concept 3: heavier projectile
  heavier frangible penetrator
  no preformed fragments

- Concept 4: heavier projectile
  equal frangible penetrator mass
  more preformed fragments

Optimisation of conceptual design (II)

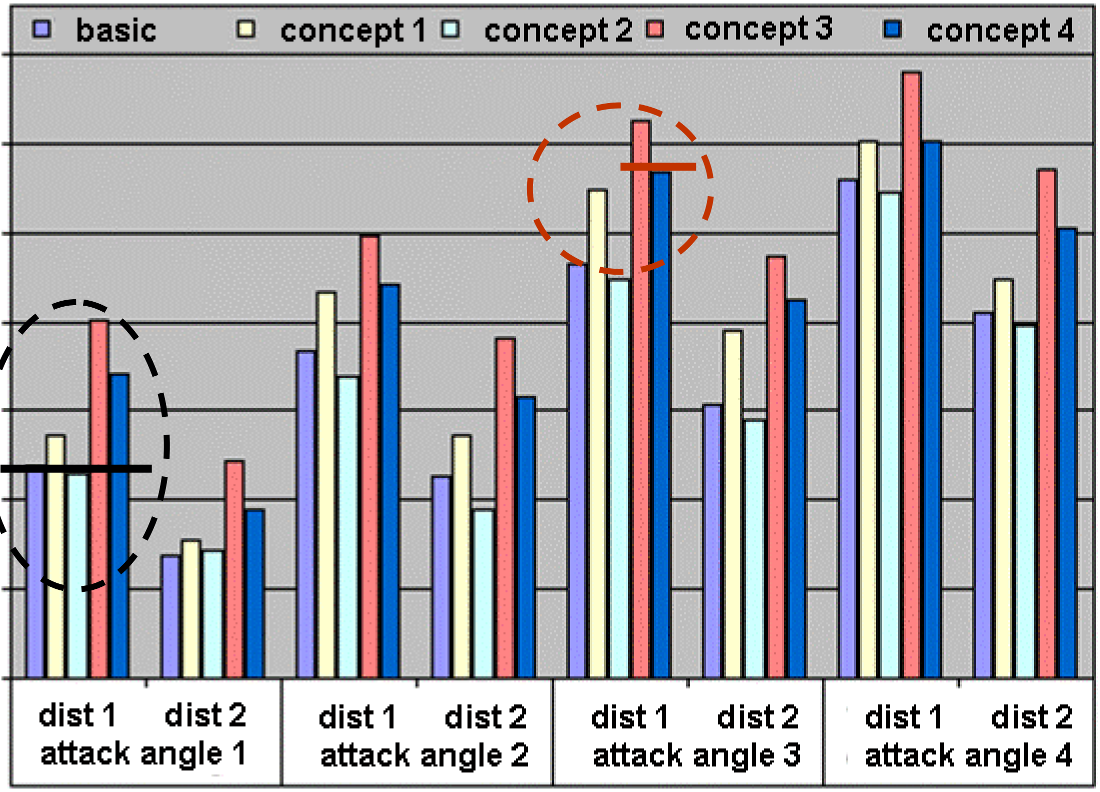
Penetration characteristics

RHA plate thickness as a function of range



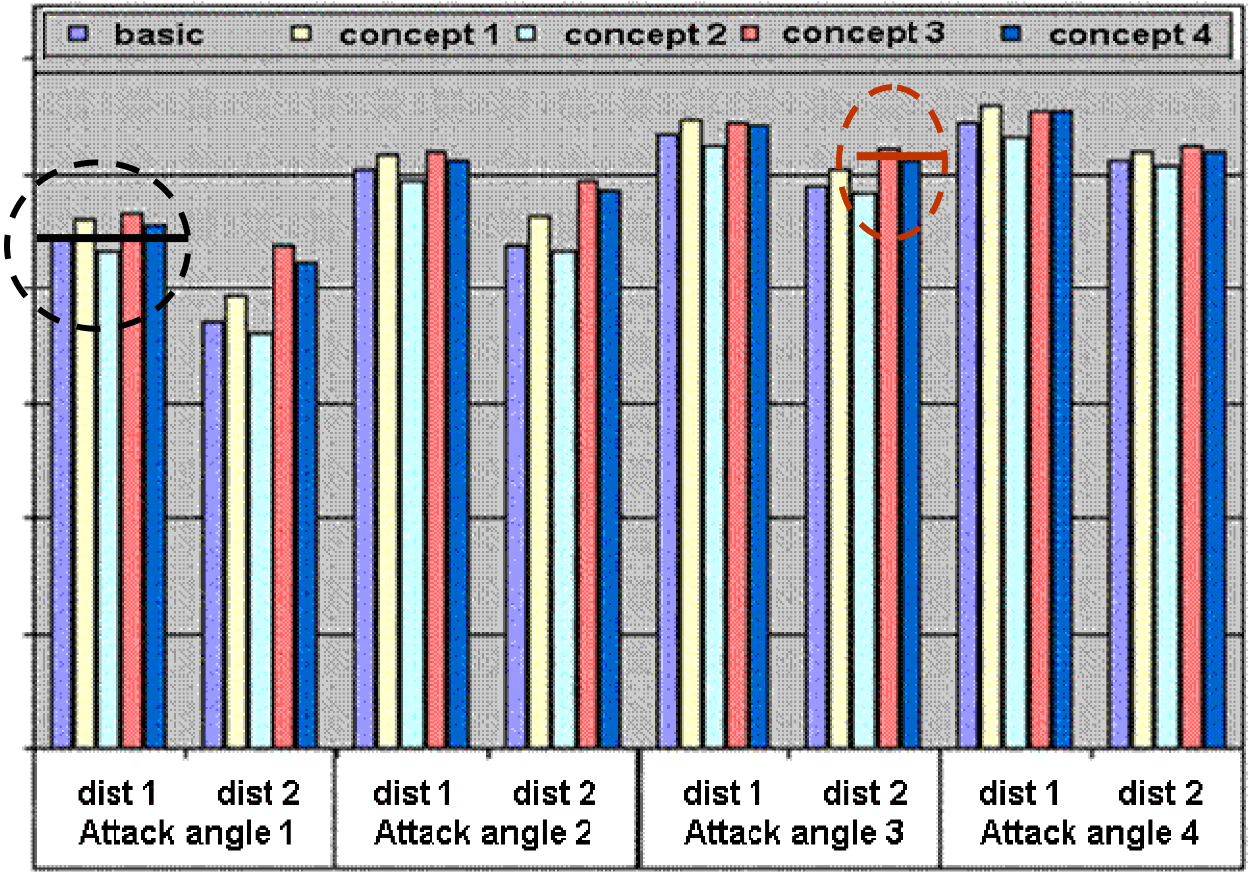
Lethality results against the BMP-2

- The fragmentation and penetration characteristics are implemented in the lethality software
- The chart presents the average SSPK given a hit on the BMP-2
- The lethality results are presented for different Slant ranges as a function of dive angles



Lethality results against the Ural4320

- The chart presents the average SSPK given a hit on the Ural4320 (loaded with ammunition boxes)



Conclusions

- Air-to-Ground:
  - Base-line version can be improved
  - Low Drag versions improve lethality for longer ranges
  - Heavier penetrator improves lethality
  - Effect of preformed fragments is minor for selected targets
- Air-to-Air:
  - The specified combat ranges are too short to result in an extra advantage for Low Drag versions
  - The difference in lethality for all considered FAP types is minor
- The FAP base-line version (already recommended LM trade study) can be improved for Air-to-Ground missions without losing Air-to-Air capability
- The selected FAP "paper" prototypes are ready for manufacturing and further development

Next phase of the 25 mm round development

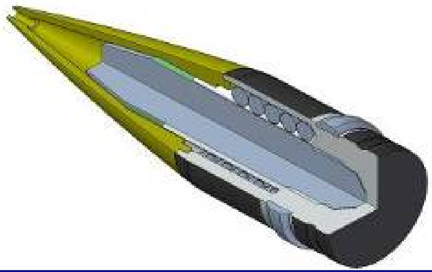
- 25 mm FAP conceptual models
- Perform firing trials
  - Validation of terminal ballistic model
  - Validation of SSPK results
- Prototype of 25 mm FAP

Trials, November 2007

- In pre-feasibility phase;
  - Penetration characteristics are determined with standard software; input data based on experiments with other (caliber) projectiles
  - Fragmentation characteristics are determined using TNO's Frangible Terminal Ballistic model:
    - makes fast, flexible, cheap projectile design changes possible
  - Simulation results have to be verified in next phase with trials
- Range targets and impact velocities are selected to verify the fragmentation and penetration characteristics of the projectiles used in the pre-feasibility phase
- Conceptual designs are based on results of pre-feasibility phase

Conceptual models selected

- Basic design):
  - frangible penetrator
  - preformed fragments



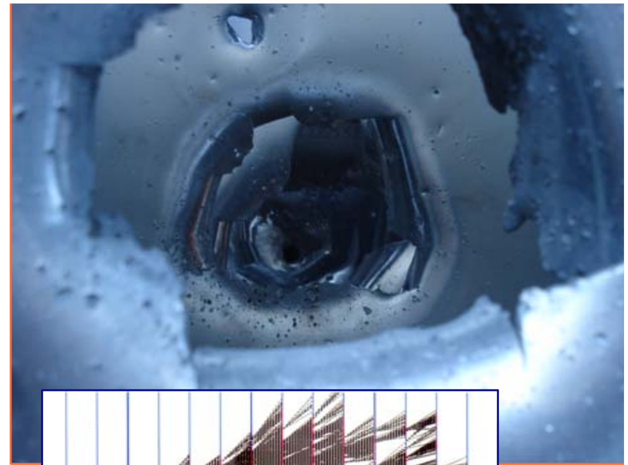
- Concept 1:
  - equal total mass
    frangible penetrator
    no preformed fragments

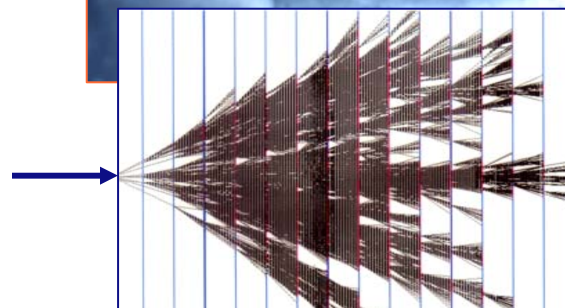
- Concept 3 :
  - heavier projectile
    heavier frangible penetrator
    no preformed fragments
  - material type X
  - Low Drag version

Concept 5 :
- see concept 3
- material type Y

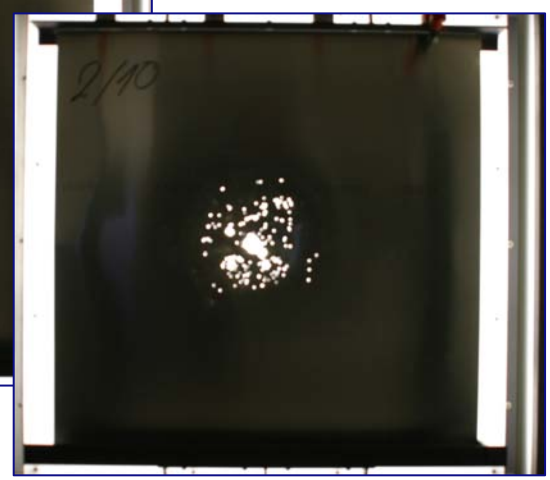
Trials

- Targets:
  - Monoblock (representing hard target)
    + after armour effect
  - Range target (representing soft target)
  - Both short and long range





Fragment trajectories

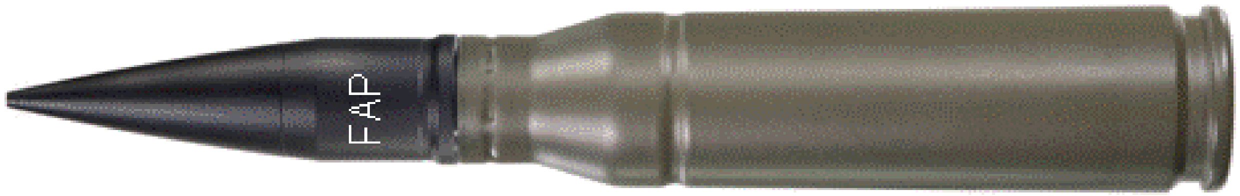


Conclusions

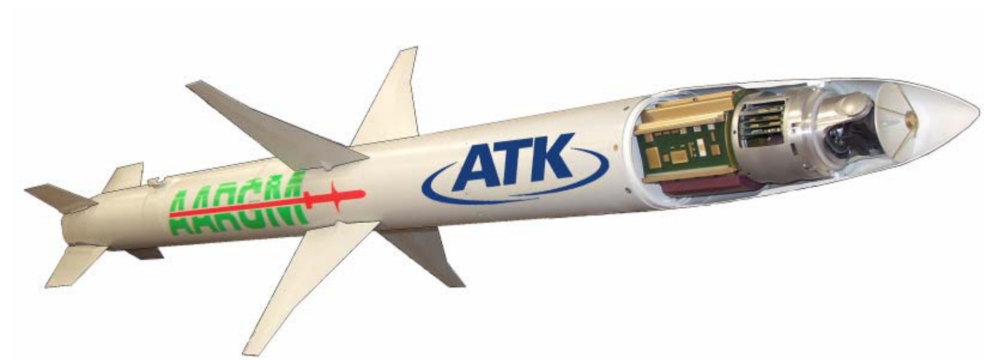
- Trials:
  - Base-line version was skipped, based on expected penetration performance in combination with costs.
  - Normal mass FAP projectile performance slightly less then used input data in pre-feasibility study
  - Higher mass FAP projectile performance slightly better then used input data in pre-feasibility study
  - In general FAP material X penetrators will have better penetration capability compared to FAP material Y penetrator
- Simulations:
  - Both heavier projectiles fulfill the RNLAF requirements
  - FAP material X shows highest lethality against hard targets
  - FAP material Y shows highest lethality against soft targets

Conclusions

- Difference between trial & simulation data is minor
- Study gives opportunity to determine design for 25mm prototype
- RWM-S has selected a design and manufactured a prototype.



Advanced Anti-Radiation Guided Missile (AARGM)



NDIA Guns & Missiles Conference
8 April 2009

Doug “Ratt” Larratt
AARGM Program Director
ATK Missiles

NAVAIR Public Release 09-187
Distribution Statement A:
“Approved for public release; distribution is unlimited”

Outline

- What is AARGM?
- Program History and Roadmap
- System Overview
- Development Schedule / Test Results
- Performance Overview
- Platform Integration
- Summary

What is AGM-88E AARGM?

International Cooperative Development

- **U.S. Navy & Italian Air Force**

Transforms AGM-88 HARM from single function Suppression-of-Enemy-Air-Defense (SEAD) role to <u>multi-mission Destruction-of-Enemy-Air-Defense (DEAD) and strike</u>:

- **Autonomous emitter detection and ID**
- **Autonomous target geo-location**
- **Versatile dual-mode seeker**
- **Lethal active terminal guidance**
- **GPS/INS precision with collateral damage control capability**
- **Data-link support for Battle Damage Assessment (BDA)**

Lethal capability against current /projected integrated air defenses and time-critical-strike targets

AGM-88E AARGM

Program History / Roadmap

AGM-88 Roadmap

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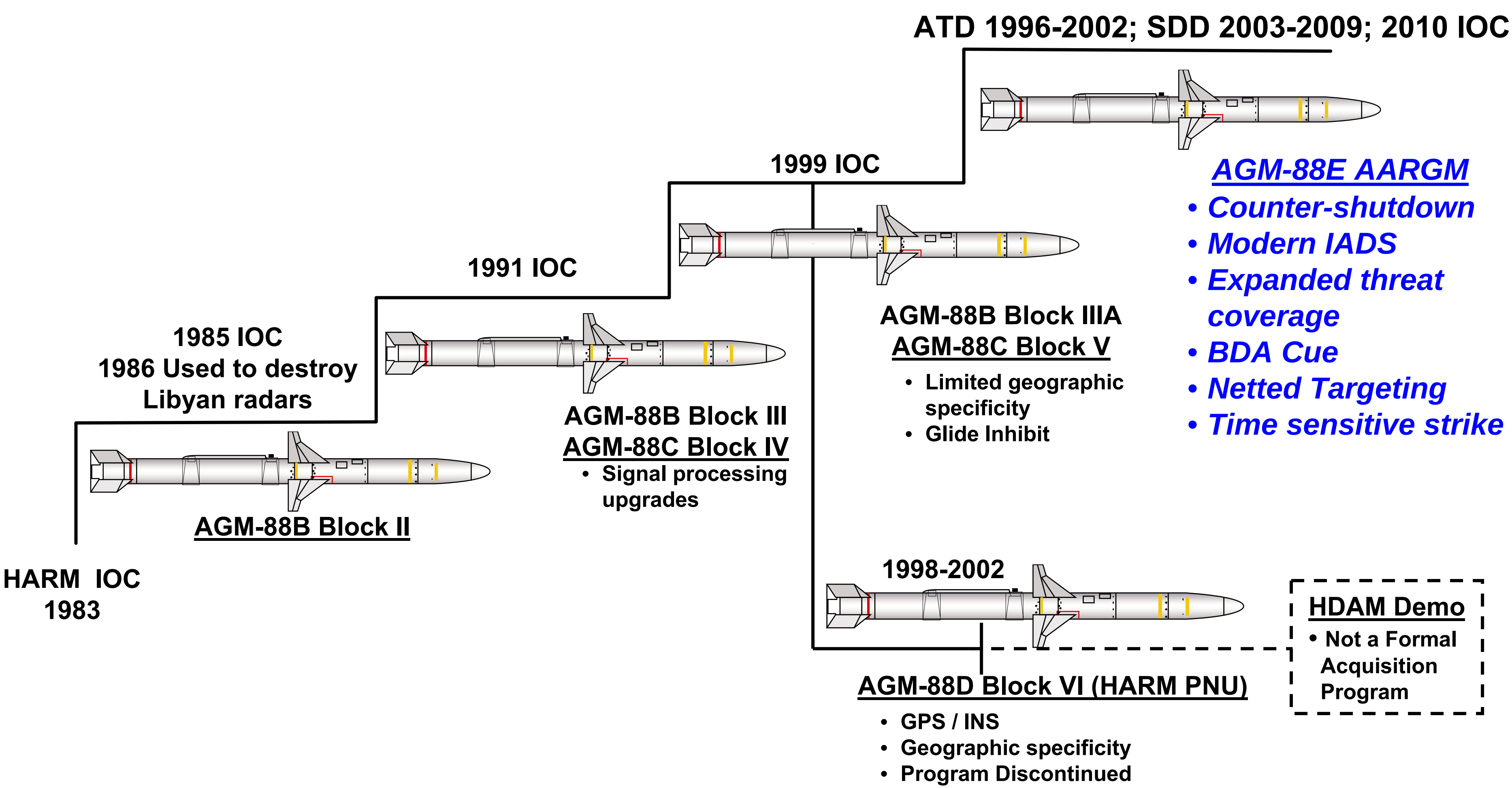

AGM-88E enables transition from Suppression (SEAD) to Destruction (DEAD) of Enemy Air Defenses

AGM-88E AARGM

System Overview

AGM-88E Advanced Anti-Radiation Guided Missile

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Capabilities

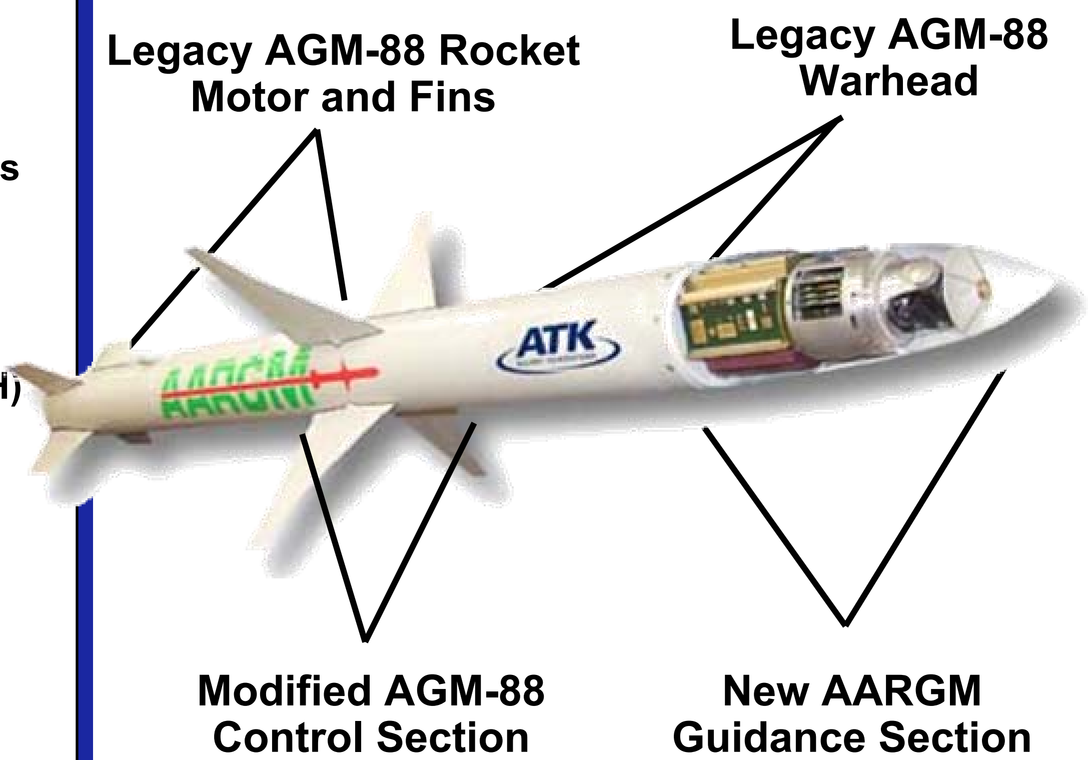
- Advanced IADS With Shutdown
- Greater Lethality
- Geographic Specificity
- BDA Support/Situational Awareness
- High Speed Strike

Sensors

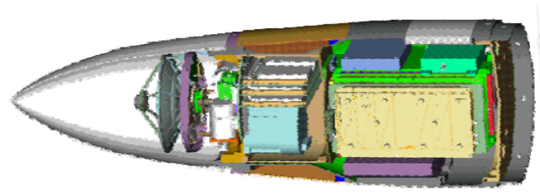
- Digital Anti-Radiation Homing (ARH)
- Active MMW Terminal Guidance
- DTED-Aided SAASM GPS / INS
- National Systems Transmitter and Receiver (US Only)
- Missile Impact Transmitter (International)

Physical (*same as HARM)*

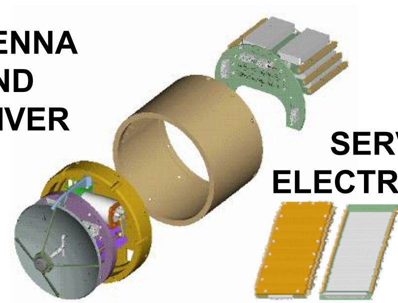
- Length - 164” (417cm)
- Diameter - 10” (25cm)
- Weight - 795 lbs (361kg)



AARGM Guidance Section

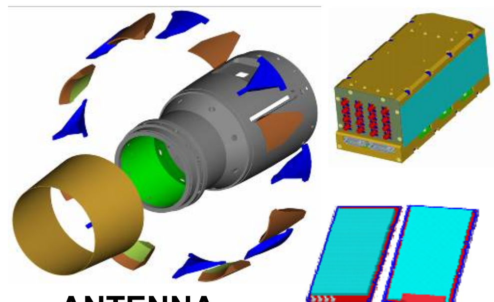


Active Radar Seeker



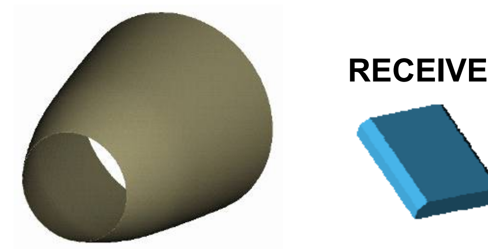
- Performs terminal target acquisition and track
- Large search area counters target movement/shutdown
- Expands AARGM target set to non-emitters

Passive Anti-Radiation Homing Seeker



- Increased sensitivity, frequency band, and field-of-view with digital design
- Autonomous target detection, Identification
- Precision DF enables on-aircraft emitter location

IBS Receiver (US Only)



- Receives off-board target information
- Fused with ARH data to form correlated target location/type/ track file
- Enables off-board queuing and enhanced cockpit situational awareness

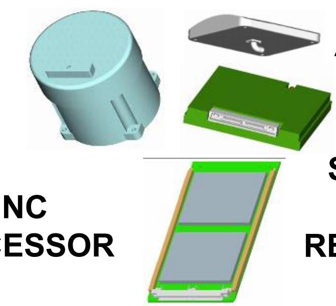
High-performance, multi-mode seeker ensures intended target destruction in countermeasures environment

AARGM Common Control Section

Guidance, Navigation, and Control Subsystem

IMU

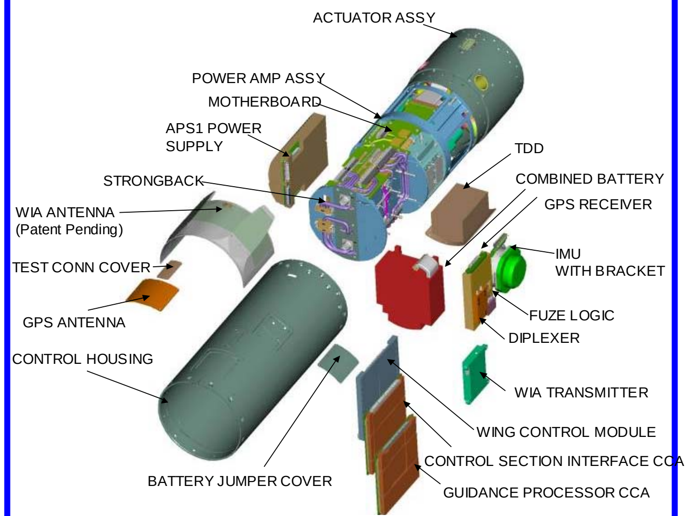
GPS ANTENNA



SAASM GPS RECEIVER

GNC PROCESSOR

- High performance INS with tightly coupled IMU/SAASM GPS RCVR integrated with DTED data
- Enables fratricide reduction and precision target engagement

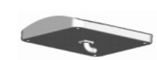


Power Subsystem

- New Power Supply
- Extended Life Battery

Weapons Impact Assessment (US Only) / Missile Impact Transmitter (International)

ANTENNA



TRANSMITTER

- Connectivity with off-board sensors
- End game transmission of missile state and impact
- Enables BDA support
- Weapons impact location verification

Modular control section design allows for <u>backward compatibility</u> with <u>legacy HARM</u> weapons for precision navigation/point-to-point capabilities as well as providing missile flight/navigation capabilities for AARGM missile

AARGM Flight Profile Overview

ATK
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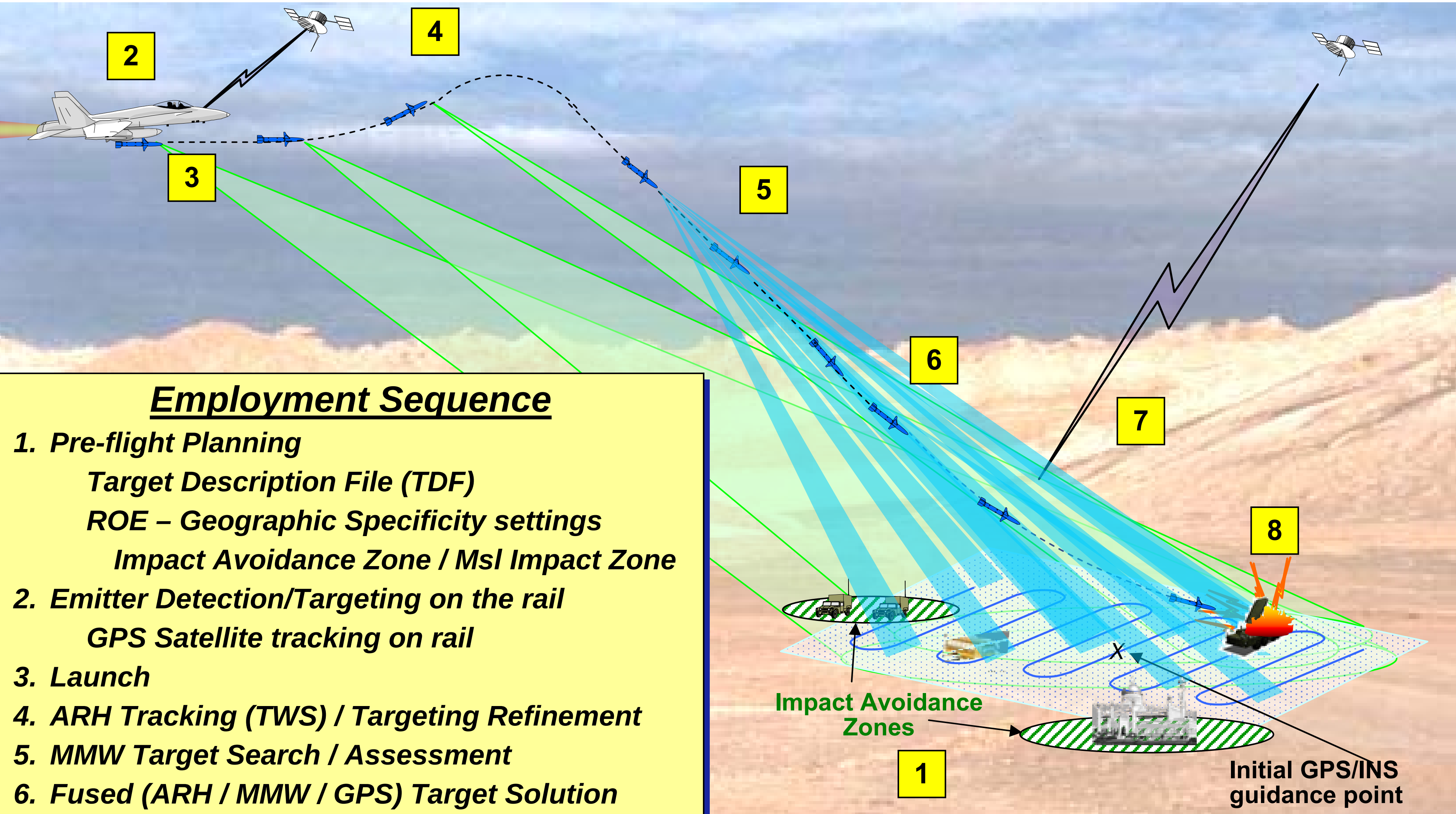

Employment Sequence

1. Pre-flight Planning
Target Description File (TDF)
ROE – Geographic Specificity settings
Impact Avoidance Zone / Msl Impact Zone
2. Emitter Detection/Targeting on the rail
GPS Satellite tracking on rail
3. Launch
4. ARH Tracking (TWS) / Targeting Refinement
5. MMW Target Search / Assessment
6. Fused (ARH / MMW / GPS) Target Solution
7. Weapon Impact Assessment Message
8. Fuzing

AGM-88E AARGM

Development Schedule / Test Results

AARGM Top Level Schedule

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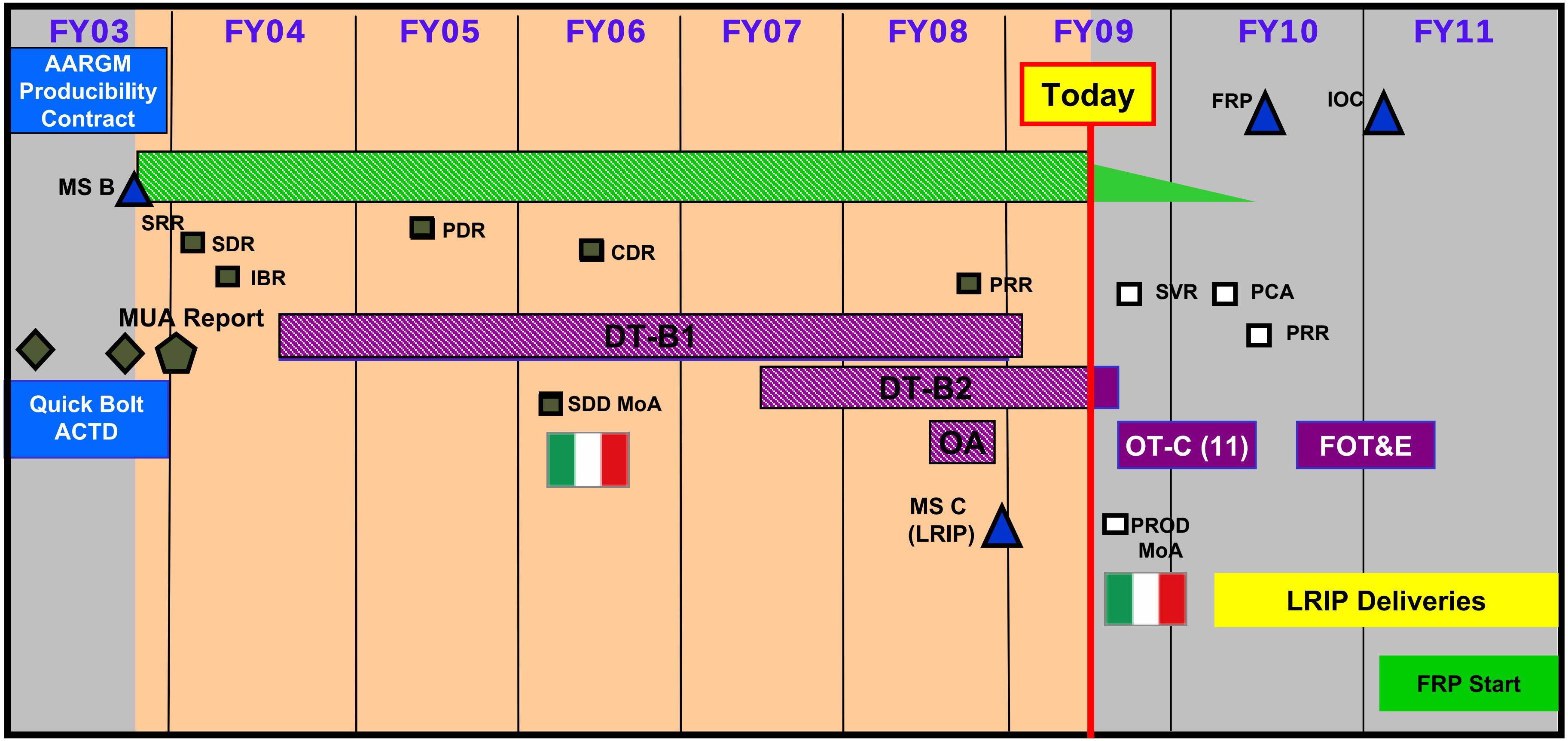

ATD – Advanced Technology Demonstration
ACTD – Advanced Concept Technology Demonstration
CDR – Critical Design Review
DT-B1 –Developmental Testing (Lab/Ground/Captive)
DT-B2 – Developmental Testing (Captive/ Firing)
FCA – Functional Configuration Audit
FOT&E – Follow-On Test and Evaluation
FRP – Full Rate Production
IBR – Integrated Baseline Review

IOC – Initial Operational Capability
MSB – Milestone B
MUA – Military Utility Assessment (Quickbolt)
MSC – Milestone C
LRIP – Low Rate Initial Production
OA – Operational Assessment
OT – Operational Testing
PCA – Physical Configuration Audit
PDR – Preliminary Design Review

PRR – Production Readiness Review
SD&D – System Development and Demonstration
SDR – System Design Review
SRR – System Requirements Review
SVR – System Verification Review

AARGM Shot History

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		Launch Date	GPS	ARH	MMW	Shut Down	Geo Spec	WIA XMIT	IBS CORR
CTV-1	ATD	3/23/2000 Success	√						
CTV-2		6/19/2000 Success	√						
GTV-1		8/28/2001 Success	√	√					
GTV-2		12/21/2001 Success	√	√	√				
GTV-3		8/29/2002 Part Success	√	√	√	√	√		
QB-1	ACTD	11/15/2003 Success	√	√	√	√	√	√	
QB-2		7/15/2003 Success	√	√	√	√	√	√	√
DT-1	SDD	5/25/2007 Success	√	*88B			√		
DT-2		2/21/2008 Success	√	√	√		√		
OA-1		8/03/2008 Success	√	√	√		√		
OA-2		8/11/2008 Success	√	√	√	√	√		

CTV – Control Test Vehicle

GTV – Guided Test Vehicle

QB – Quickbolt

DT – Developmental Test Firing

OA – Operational Assessment Test Firing

*w/ AGM-88B seeker





AARGM OA-2 / DT-4 Test Summary

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Test Objective

Lethal engagement of a radiating air defense unit employing shutdown in a restricted ROE (rules of engagement) environment

Improvements over HARM

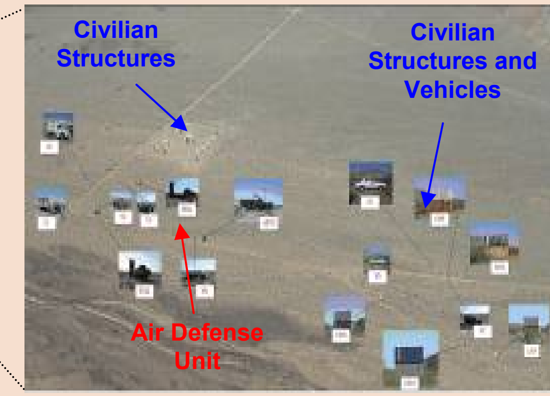
•Defeating Shutdown

•Preventing Collateral Damage

Test Scenario

Flight Profile

Target Area



Test Results

- 7 of 7 Success Criteria Demonstrated
  - – Shutdown Defeated
  - – Civilian structures not engaged
  - – Air Defense Unit Lethally Engaged
    - - Direct Hit
    - - Probability of Kill > requirement

OA-2 Telemetry-Based Video

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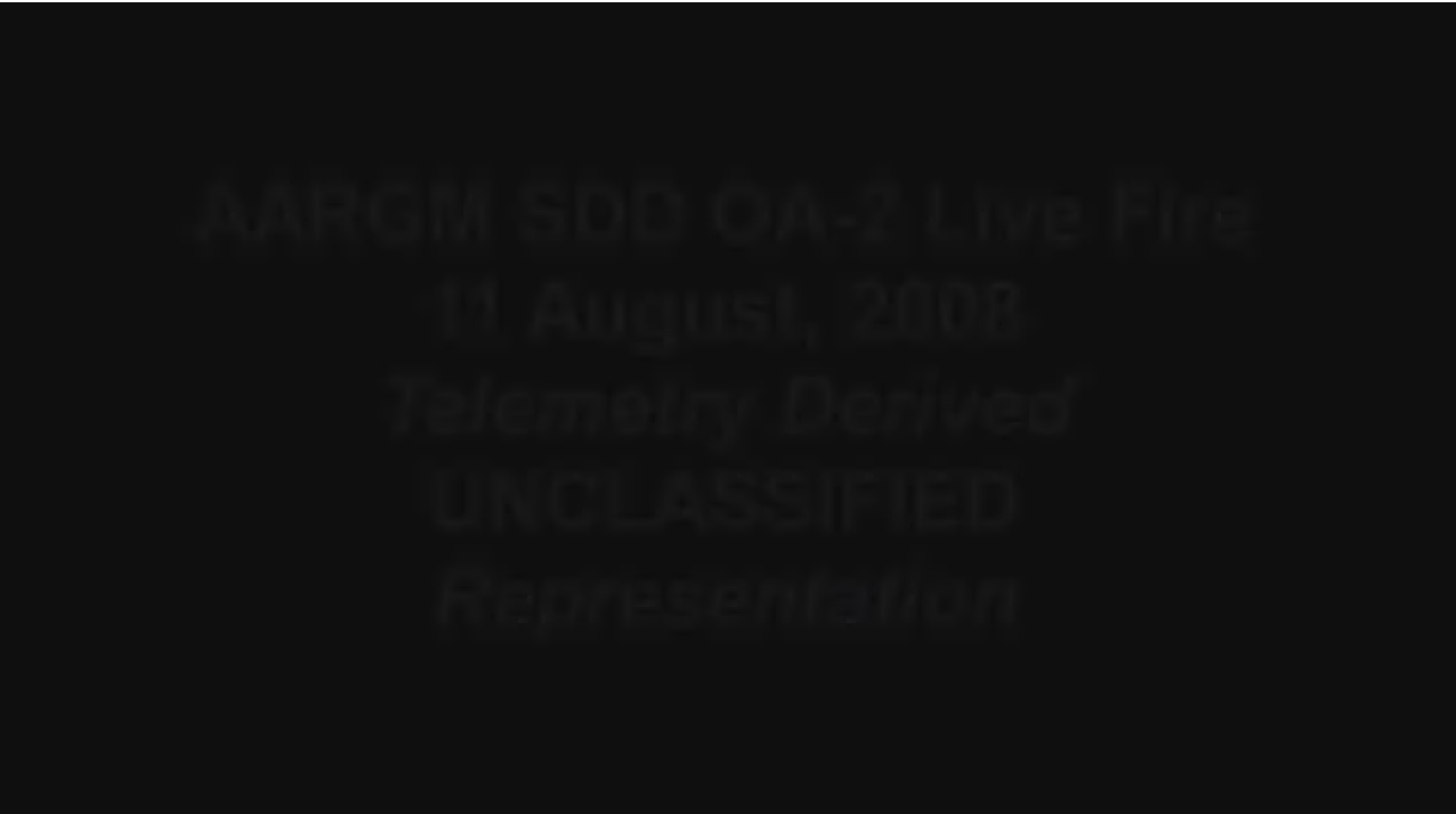
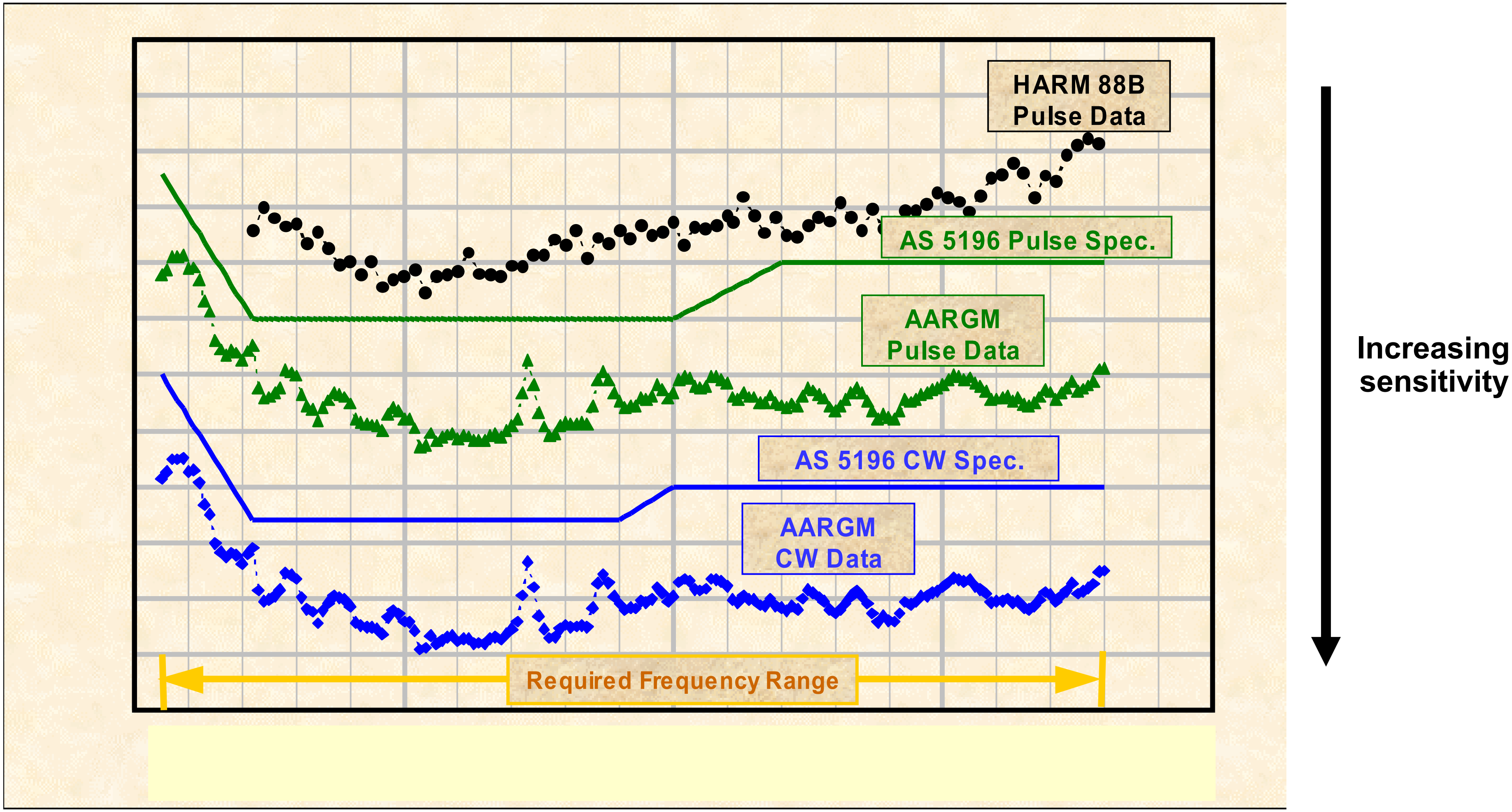


AGM-88E AARGM

Performance Overview

ARH Subsystem – Sensitivity/Detection Range



Meets threshold frequency range and significantly exceeds legacy HARM detection sensitivity

Situational Awareness & Targeting Enhancements

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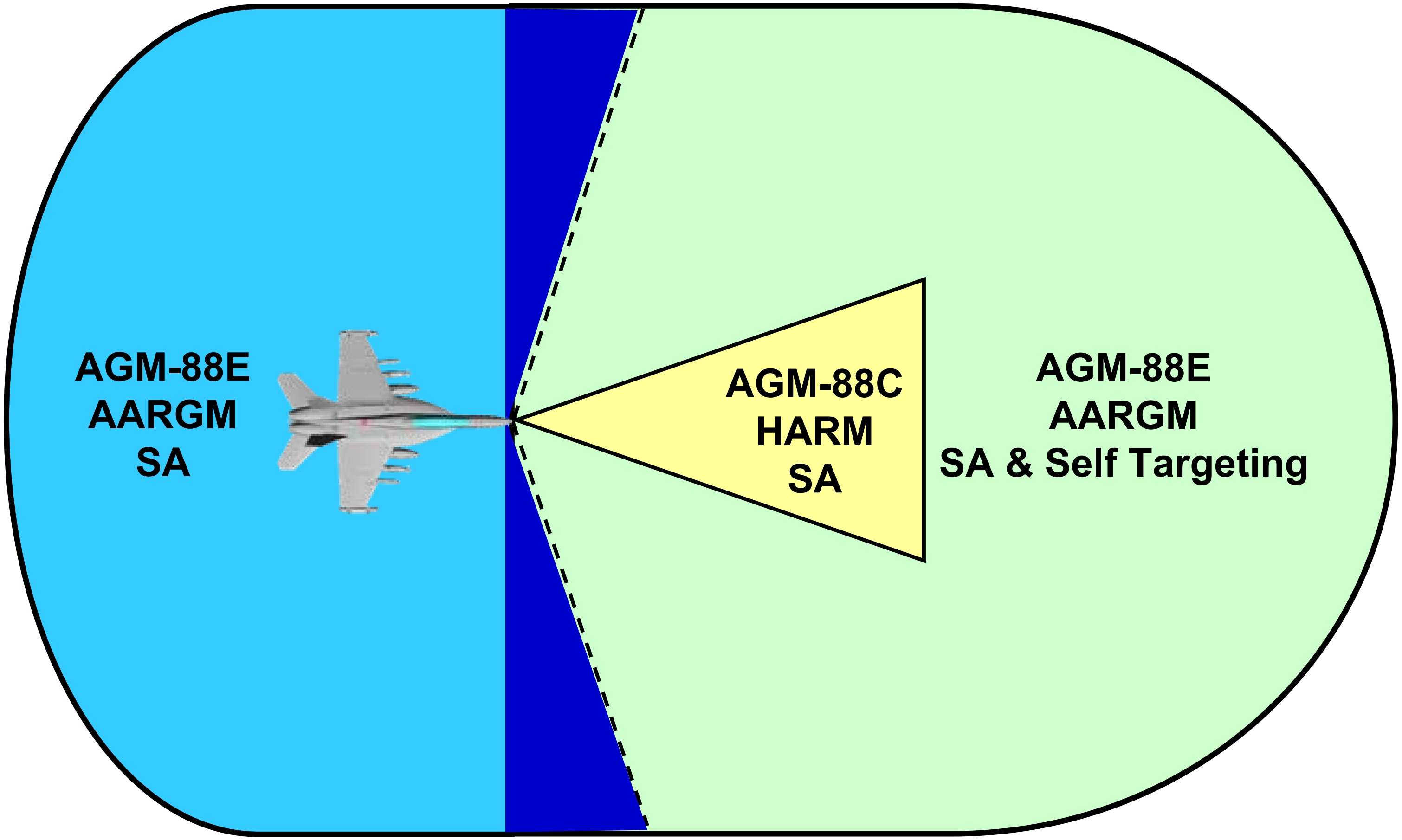

SA – Situational Awareness with network connectivity

AARGM Comparison / Demonstrated Test Results

ATK

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Operational Capabilities

PNU – Precision Navigation Upgrade

CCS – Common Control Section

DT – Developmental Test Firing

OA – Operational Assessment Test Firing

BFT – Beech Flight Test

X – Demonstrated

Mode	HARM	PNU	CCS	AARGM
Emitter Engagement	X	X	X	X (OA-1)
Exclusion Zones		X	X	X (OA-2)
Stationary Non-Emitter		X	X	X (DT-1)
Point to Point Attack		X	X	X (DT-1)
BDA Support			X	X (QB-2)
Shutdown Tactics				X (OA-2)
Advanced Emitters				X (OA-2)
Expanded Freq Coverage				X (BFT)
Increased Detection Range				X (OA-1)
Increased DF Accuracy				X (OA-2)
Expanded Field of View				X (BFT)
Self Targeting				X (OA-2)

AARGM CCS Configuration with HARM Seeker

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<u>AARGM DT-1 Missile Firing</u>

- **25 May 2007 / China Lake Test Range, CA**

<u>Objective</u>:

- **Demonstrate Long-Range GPS Point-to-Point Engagement beyond 50NM**

<u>Test Configuration:</u>

- **AARGM Common Control Section (CCS) mated with legacy AGM-88B HARM seeker**

<u>Results</u>

- **Direct Hit on GPS Target**
- **Demonstrated compatibility of AARGM CCS with legacy AGM-88B Seeker**
    - **Legacy AGM-88B Seeker activation and detection of emitter signals**

GPS Pt-to-Pt Targeting (DT-1)

AGM-88E AARGM

Platform Integration

Platform Integration Plan

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Platform Integration / GFY		07	08	09	10	11	12	13
 F/A-18 C/D	Baseline USN AARGM Platform (OFP 21X)	DT			OT	IOC	Fielding	
 F/A-18 E/F	Planned Funding in PR09				Design & Development			Fielding
 Tornado	Italian ECRs Planned				Design & Development		Fielding	
 EA-18G	Planned Funding in PR09				Design & Development			Fielding
 F-35 JSF	External Only Block 6	*USN / USMC / Int'l TBD*						
 EA-6B	To be determined	*Feasible, but not currently funded*						
 F-16	HDAM/PNU interface design compatibility	*Feasible, but not currently funded*						

Summary

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Transformational AARGM design provides greatly enhanced:

- **Lethality against advanced IADS employing shutdown tactics**
- **Capability vs. mobile / time-sensitive targets**
- **Collateral Damage / Fratricide Management and Control**
- **Battle Damage Assessment Support**

AARGM is in Low Rate Production TODAY – Milestone C Sept 2008

- **Initial Operational Capability (IOC) in Nov 2010 on the FA-18C/D**
- **Integration on Italian ECR Tornado, FA-18E/F, and EA-18G is underway**
- **Compatible with the F-16**
  - **Identical to HARM in mass properties and aerodynamics**
  - **AARGM Interfaces derived from existing HARM and J-Series interfaces currently implemented**

AARGM Contact Information

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For follow-up information or questions regarding the AARGM program please contact:

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OR

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Mobile: 1.818.456.7204
E-mail: gordon.turner@atk.com

Acronyms / Abbreviations

- AARGM – Advanced Anti Radiation Guided Missile
- A/C – Aircraft
- ACAT – Acquisition Category
- ACTD – Advanced Concept Technology Demonstration
- AGM – Air-launched Guided Missile
- AOR – Area of Responsibility (Regard)
- ARH – Anti Radiation Homing
- ATD – Advanced Technology Demonstration
- ATK – Alliant Techsystems, Inc.
- BDA – Battle Damage Assessment
- CATM – Captive Air Training Missile
- CCS – Common Control Section
- CDR – Critical Design Review
- CEP – Circular Error of Probability
- CFT – Captive Flight Test
- CLC – Command Launch Computer
- DEAD – Destruction of Enemy Air Defenses
- DF – Direction Finding
- DT – Developmental Test
- Freq – Frequency
- GFE – Government Furnished Equipment
- GNC – Guidance Navigation and Control
- GPS – Global Positioning System
- HARM – High speed Anti Radiation Missile
- HDAM – HARM Destruction of Enemy Air Defenses (DEAD) Attack Module
- IADS – Integrated Air Defense Systems
- IAZ – Impact Avoidance Zone
- ID – Identification
- IMU – Inertial Measurement Unit
- INS – Inertial Navigation System
- Int'l – International
- IOC – Initial Operating Capability
- JMPS – Joint Mission Planning System
- MIT – Missile Impact Transmitter
- MIZ – Missile Impact Zone
  Mls - Missile
- MMW – Millimeter Wave
- MoD – Ministry of Defense
- OPNAV – Office of the Chief of Naval Operations
- OT – Operational Test
- PDR – Preliminary Design Review
- PNU – Precision Navigation Unit
- RCVR – Receiver
- ROE – Rules of Engagement
- SA – Situational Awareness
- SAASM – Selective Availability Anti Spoofing Mode (GPS)
- SDD (SD&D) – System Design & Development
- Spec – Specification
- TCS – Time Critical Strike
- TLE – Target Location Error
- WAU – Warhead Assembly Unit
- XCEIVER -- Transceiver

DoD Instruction 5000.02
dated 8 December 2008

Operation of the Defense Acquisition System
Statutory and Regulatory Changes

Karen Byrd
Learning Capabilities Integration Center
April 2009

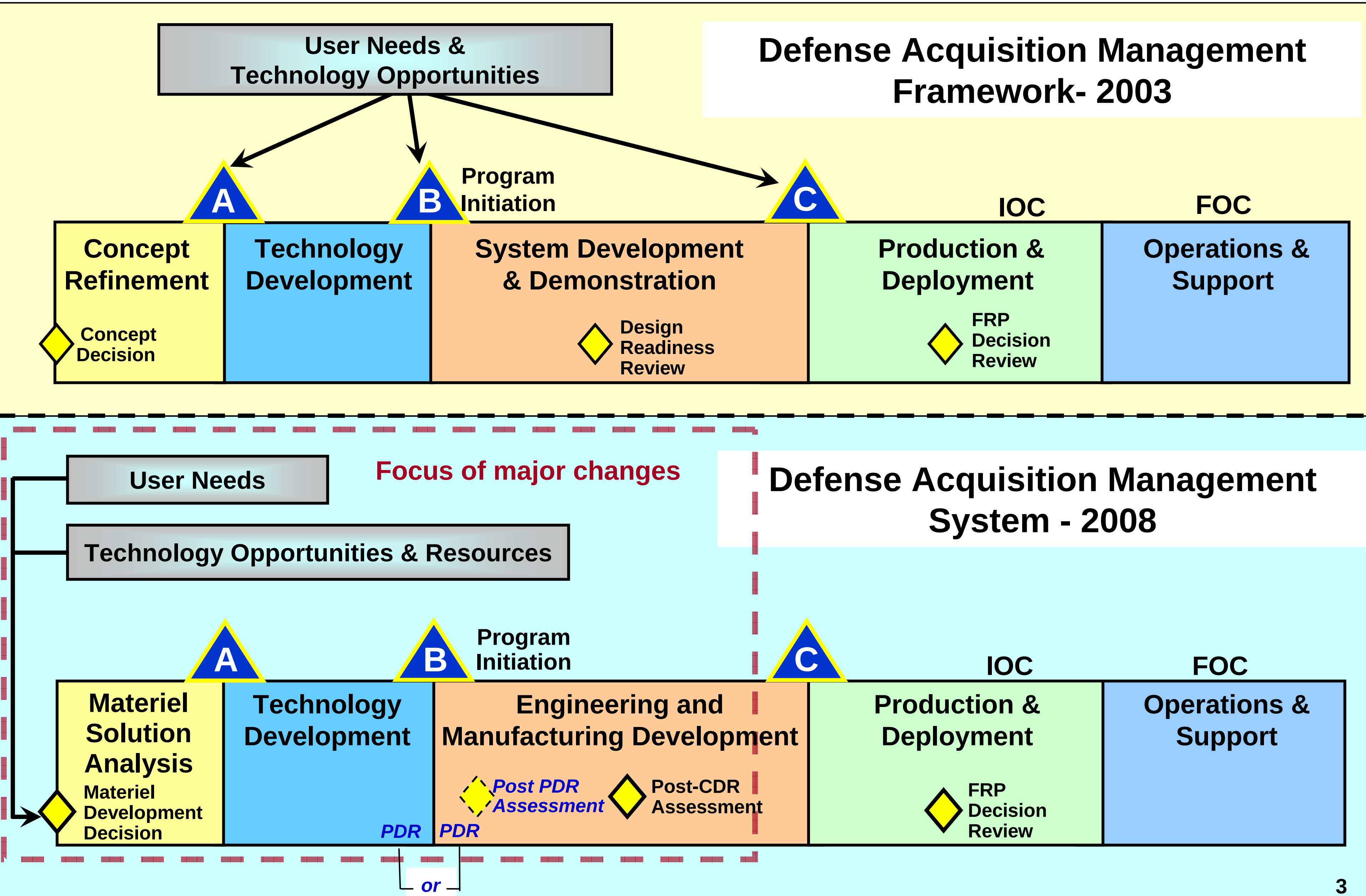
Changes to the May 2003 DoDI 5000.2

- Policy Flowing from Numerous New/Revised sections of Public Law since 2003 (some with Multiple Requirements)
- Approved Policy Appearing in over 25 Policy Memos and DoD Responses to the GAO, IG, and Congress
- Reference to 10 Updated or Newly Issued DoD Publications
- Consideration of Over 700 Defense Acquisition Policy Working Group (DAPWG) Comments

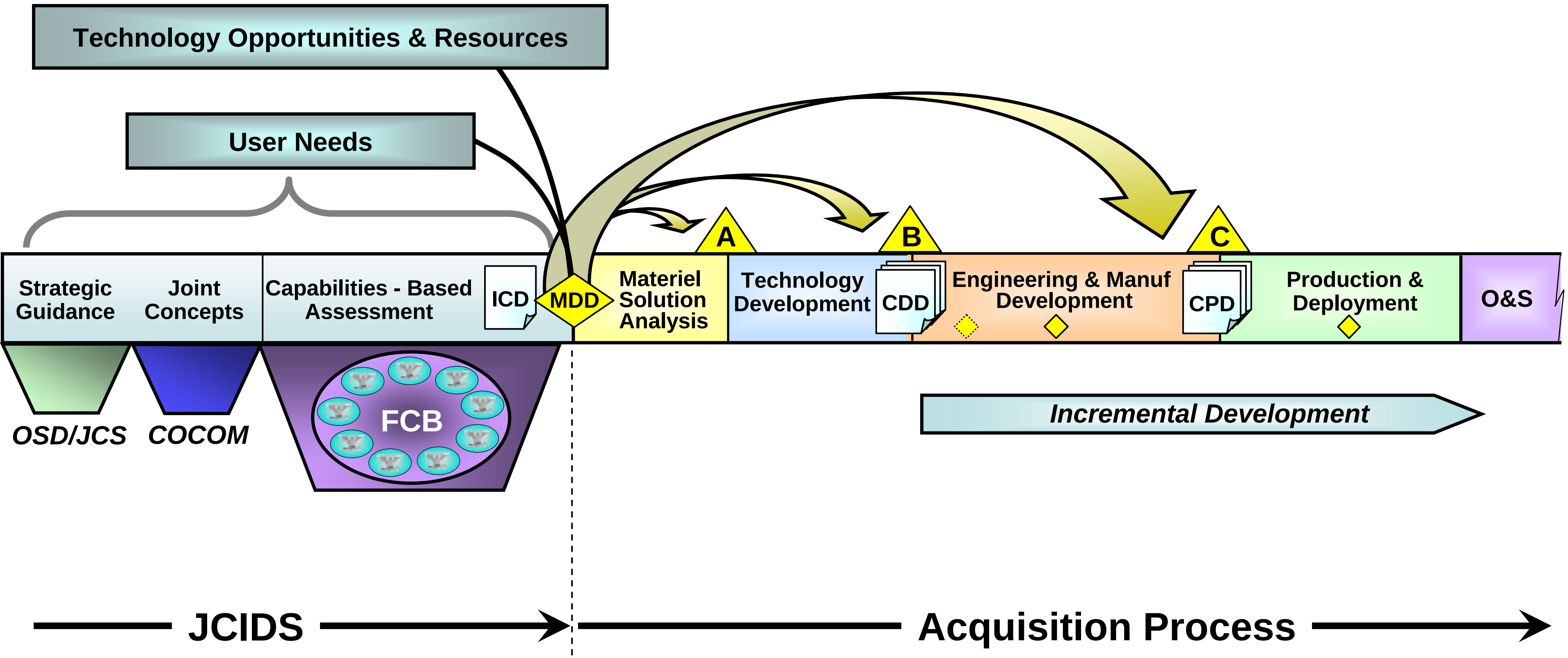
Motivations for the Revision of DoDI 5000.2

- Most potential programs were proceeding to Milestone B without a predecessor review to assess the capability need and direct of analysis of alternatives
- Technical maturity not adequately demonstrated prior to program initiation
- Program cost, schedule, and performance inadequately informed by design considerations
- Requirements “creep” continuing to destabilize programs
- No formal and effective opportunity between Milestone B and Milestone C for MDA to assess progress, adjust/defer requirements or, consistent with statute, restructure the program

Comparison of 2003 vs. 2008



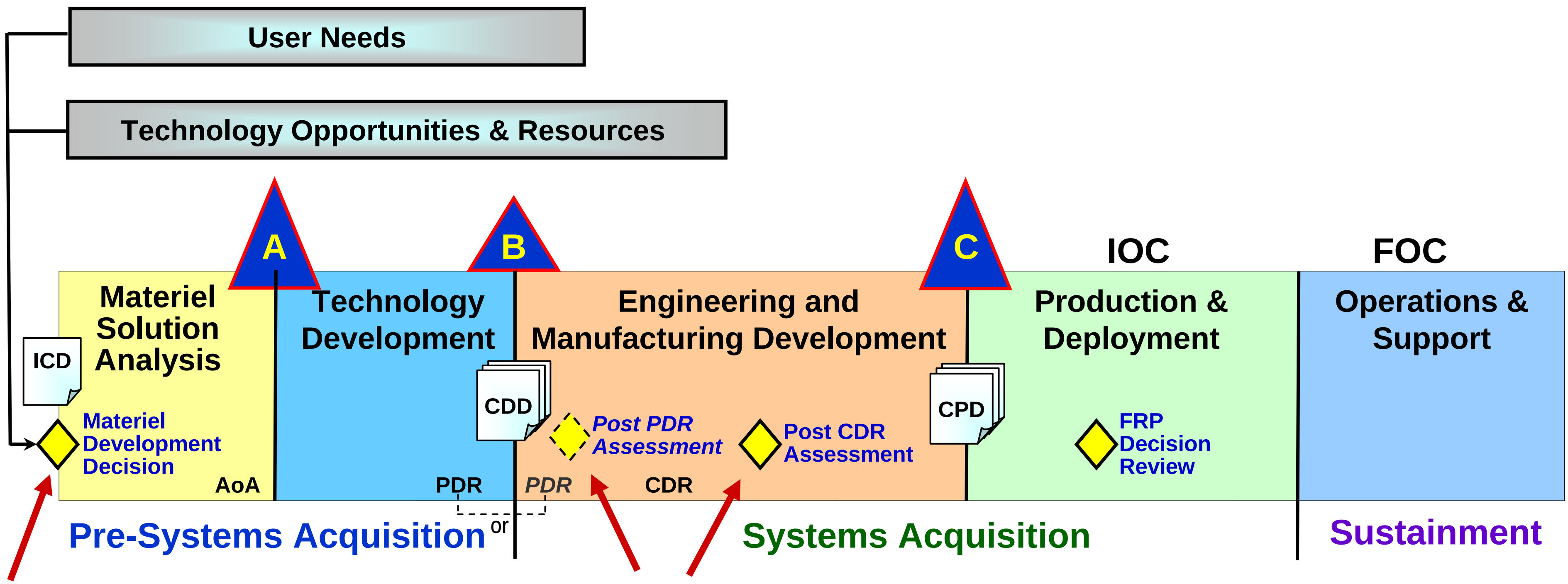
The Defense Acquisition Management System 2008



"Following the Materiel Development Decision (MDD), the MDA may authorize entry into the acquisition management system at any point consistent with phase-specific entrance criteria and statutory requirements."

Defense Acquisition University

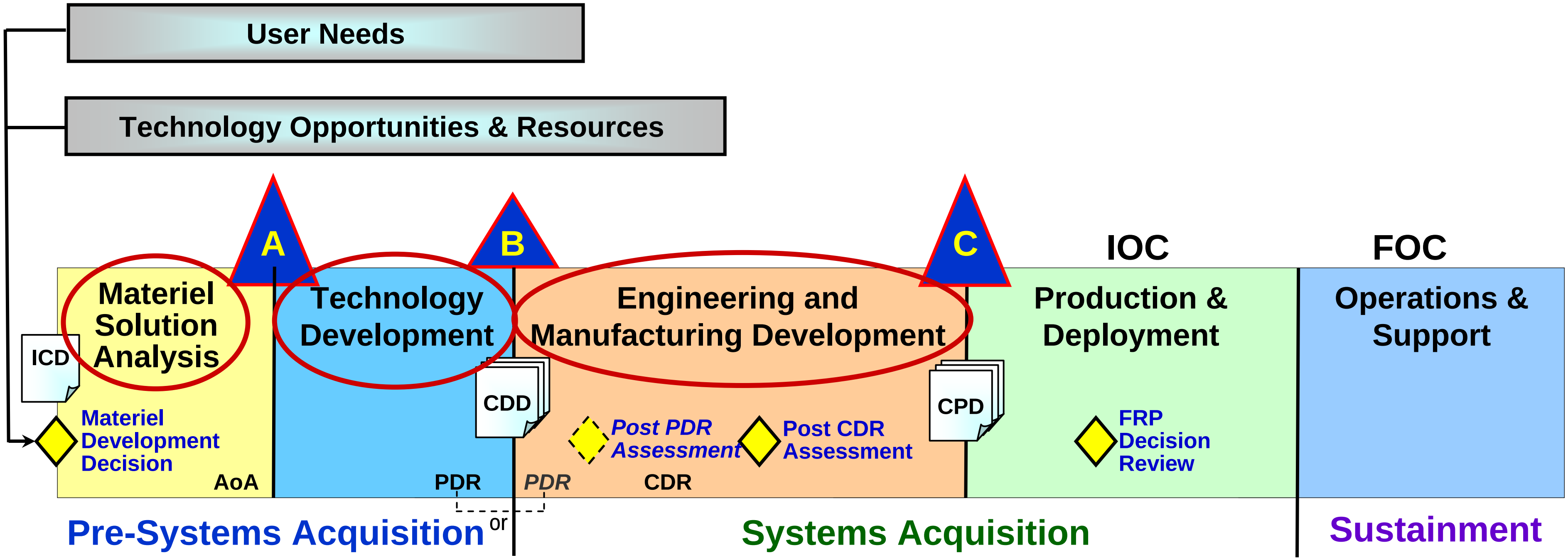
The Defense Acquisition Management System 2008



Changes to Decision Points

Old (2003)	New (2008)	Change from 2003
Concept Decision (CD)	Materiel Development Decision (MDD)	MDD required prior to entering the process at any point
N/A	*Post-PDR Assessment*	*MDA's assessment of PM's PDR Report (if PDR after MS B)*
Design Readiness Review DRR	Post-CDR Assessment	MDA's assessment of PM's CDR Report

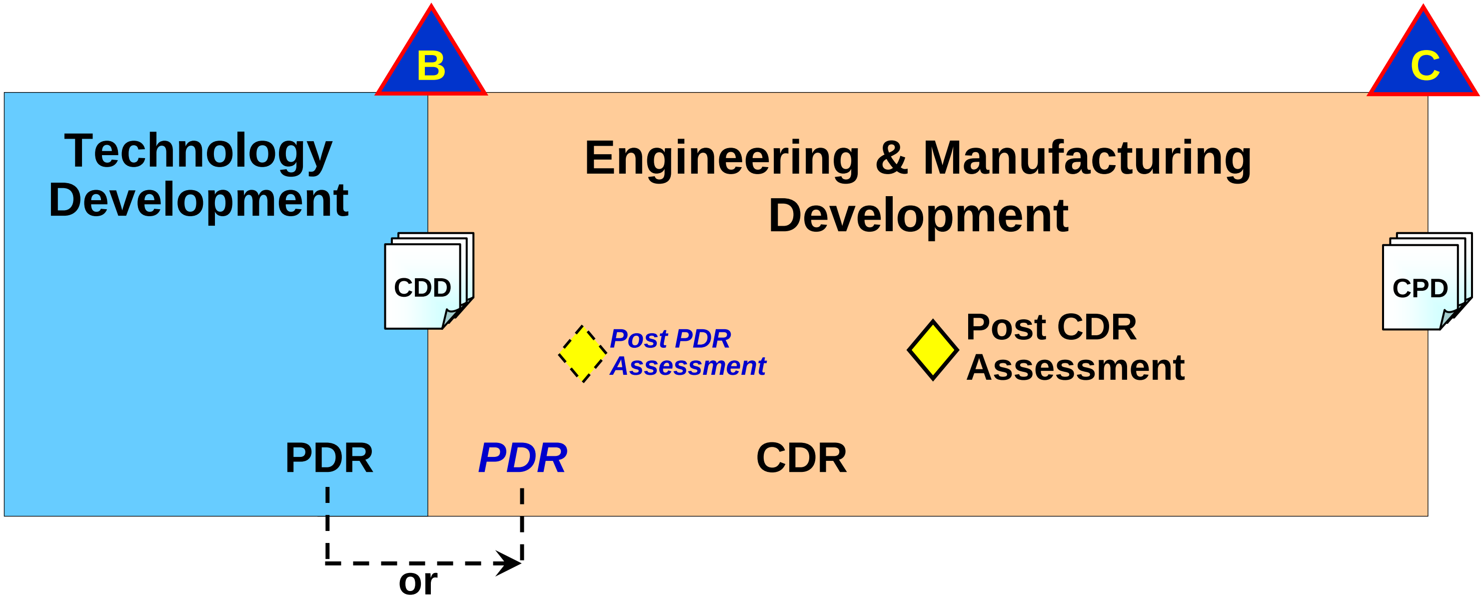
The Defense Acquisition Management System 2008



Changes to Phases

Old (2003)	New (2008)	Change from 2003
Concept Refinement (CR)	Materiel Solution Analysis	More robust AoA (result of changes to JCIDS)
Technology Development (TD)		Competitive prototyping
Systems Development & Demonstration (SDD)	Engineering & Manufacturing Development (EMD)	More robust system engineering

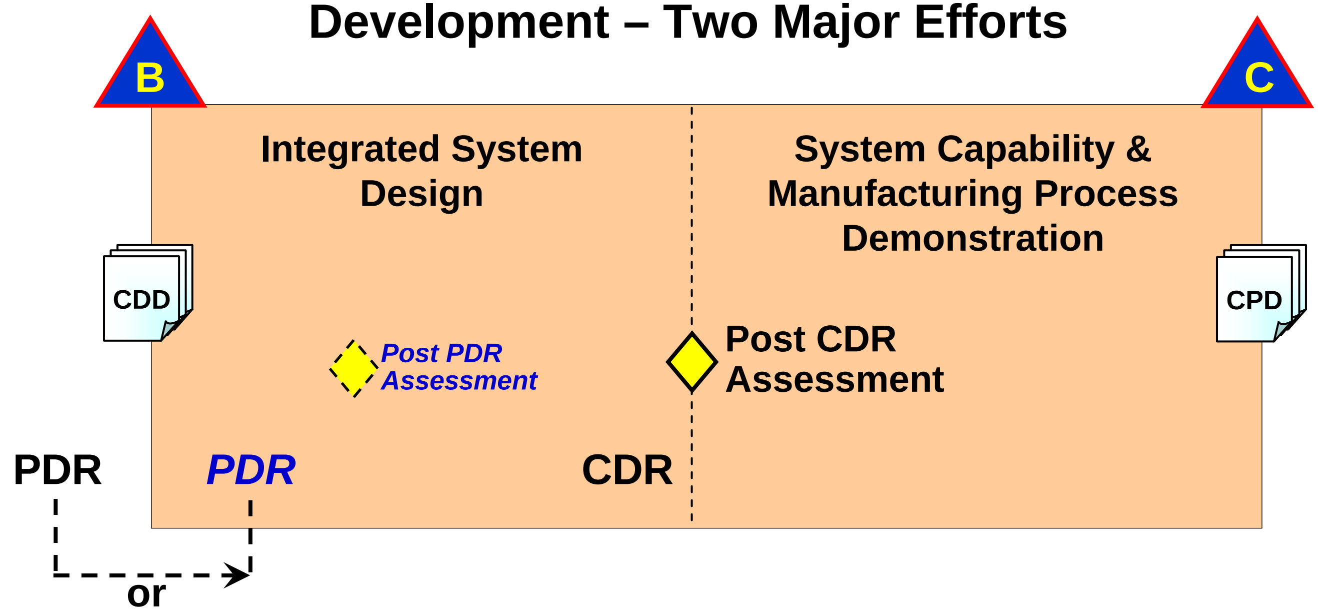
Preliminary Design Review



PDR Before Milestone B	PDR After Milestone B
• Planned for in Technology Development Strategy • PDR Report provided to MDA at MS B • Includes recommended requirements trades	• Planned for in Acquisition Strategy • PDR Report provided to MDA prior to Post PDR Assessment • Reflects requirements trades • At Post PDR Assessment, MDA considers PDR report; determines action(s) required to achieve APB objectives and issues ADM

The Defense Acquisition Management System 2008

Engineering & Manufacturing Development – Two Major Efforts

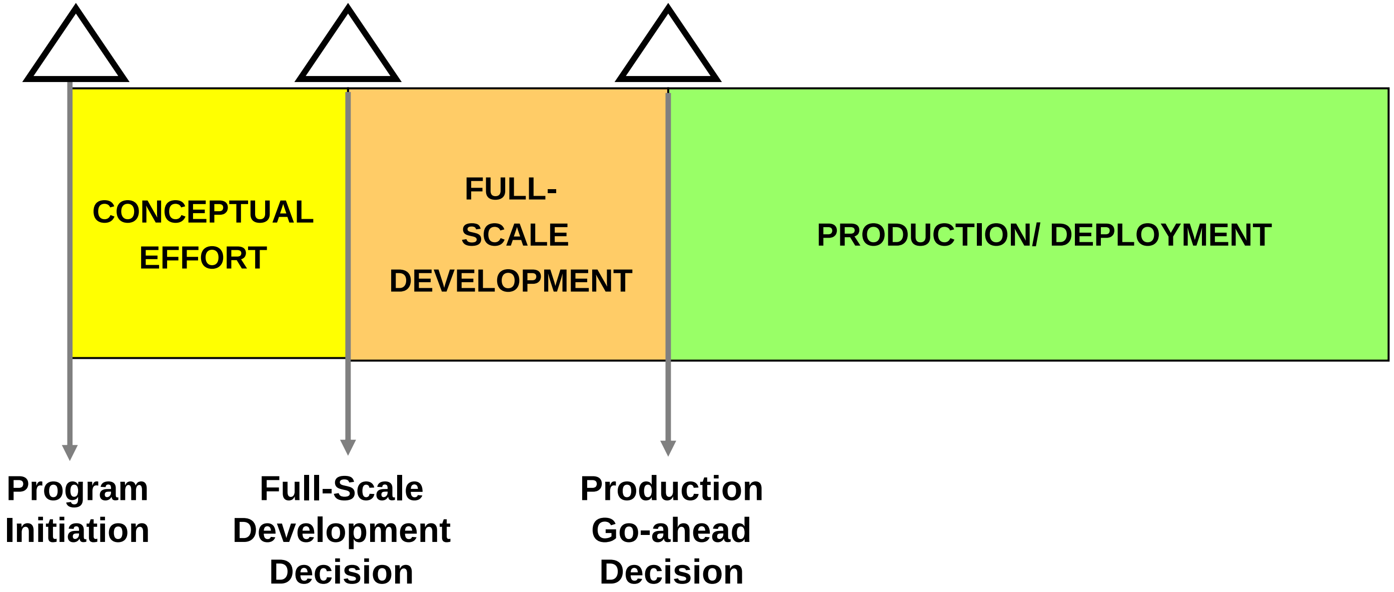


Old (2003)	New (2008)	Change from 2003
System Design	Integrated System Design	Establishment of Product Baseline for all Configuration Items
System Demonstration	System Capability & Manufacturing Process Demonstration	Manufacturing processes effectively demonstrated; production-representative article(s) demonstrated in intended environment; T&E assesses improvements to mission capability and operational support based on user needs.

Now for the Acquisition Management System

We will “walk through” the process and highlight major changes

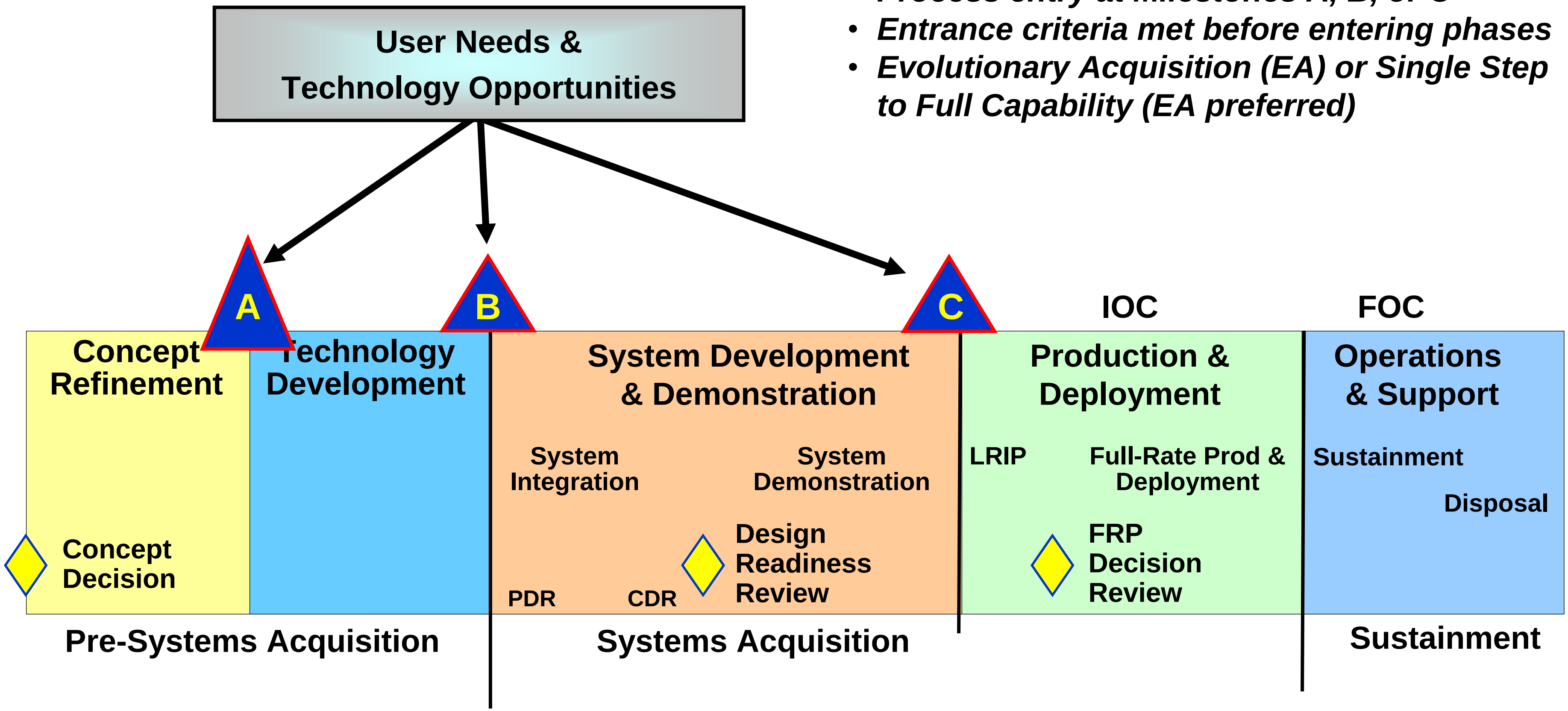
First Acquisition Framework in 1971



- **Decision points: 3**
- **Phases: 3**
- **Milestone documents: 1 (Decision Coordinating Paper (DCP))**

The Defense Acquisition Framework 2003

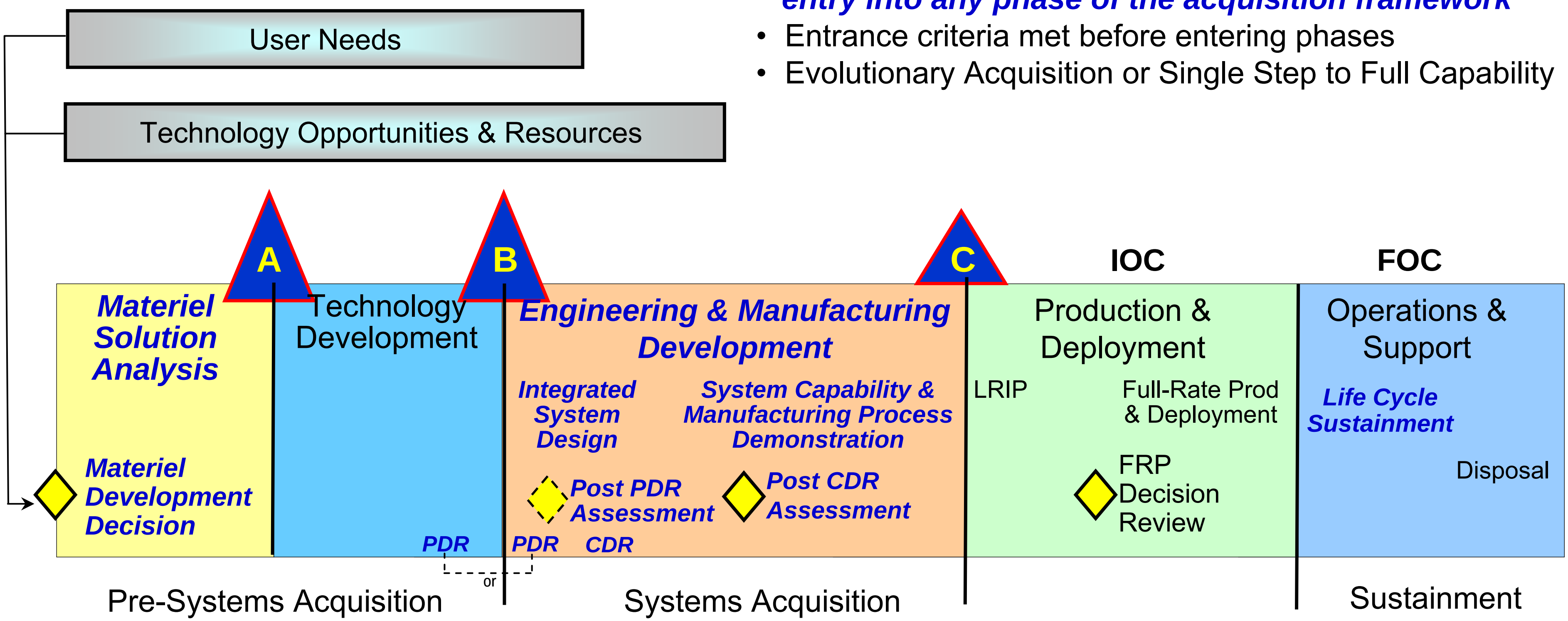
- *Process entry at Milestones A, B, or C*
- *Entrance criteria met before entering phases*
- *Evolutionary Acquisition (EA) or Single Step to Full Capability (EA preferred)*



- **Decision points: 6**
- **Phases: 5**
- **Milestone documents: 30+**

The Defense Acquisition Management System 2008

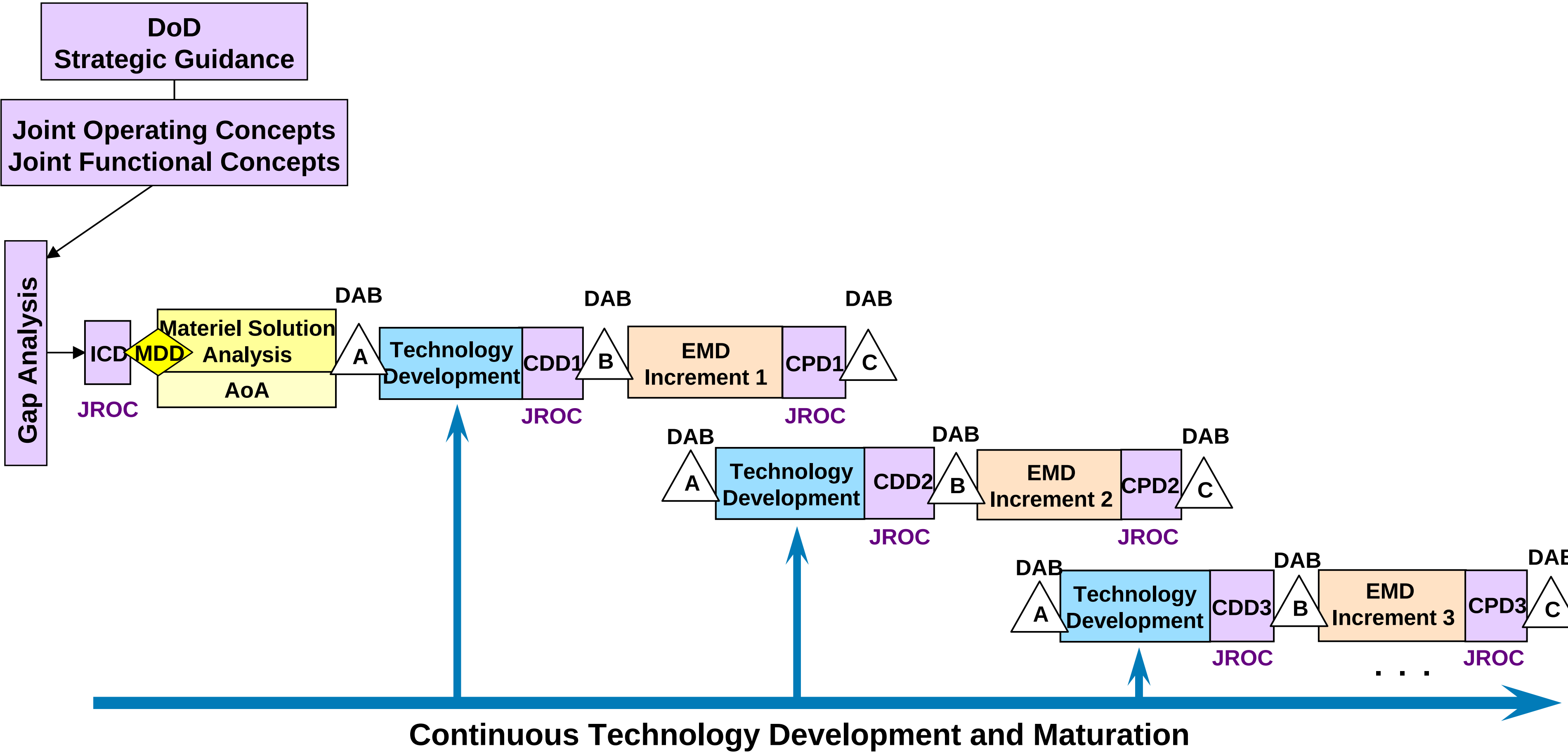
- ***The Materiel Development Decision precedes entry into any phase of the acquisition framework***
- Entrance criteria met before entering phases
- Evolutionary Acquisition or Single Step to Full Capability



- Decision points: 6
- Phases: 5
- Milestone documents: ***40+***

New in *bold blue italics*

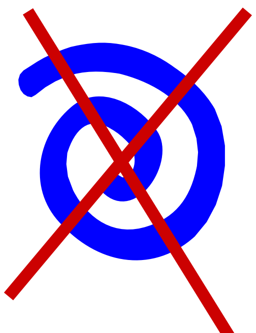
Evolutionary Approach



Evolutionary Acquisition

From two processes… → **To one process…**

- Incremental Development: End-state is known; requirements met over time in several increments
- Spiral Development: End-state is not known; requirements for increments dependent upon technology maturation and user feedback.

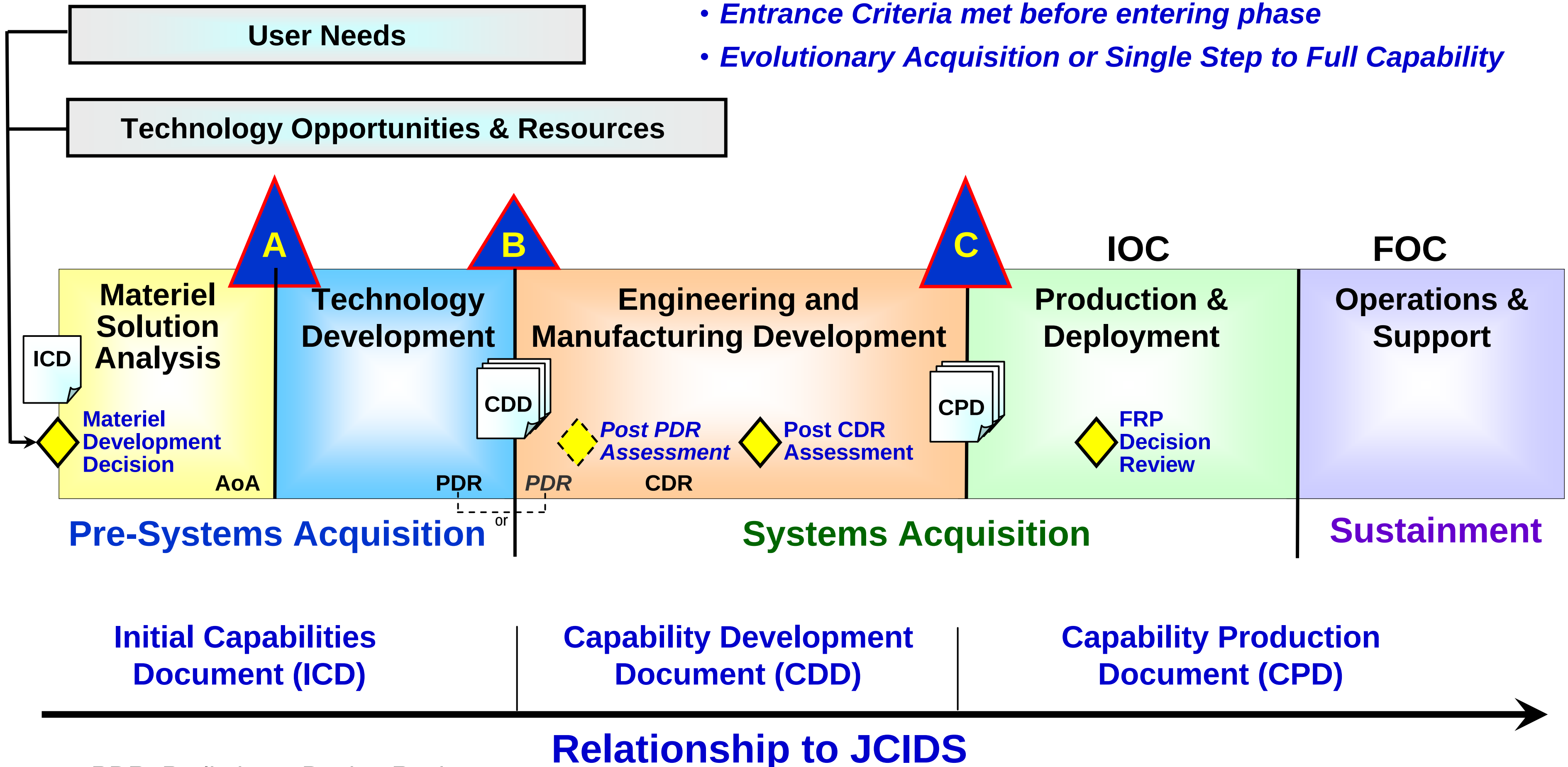


No spirals!

- Capability delivered in increments, recognizing up front need for future capability improvements
- Each increment:
  - depends on mature technology
  - is a militarily useful and supportable operational capability
  - Successive Technology Development Phases may be needed to mature technology for multiple increments

The Defense Acquisition Management System

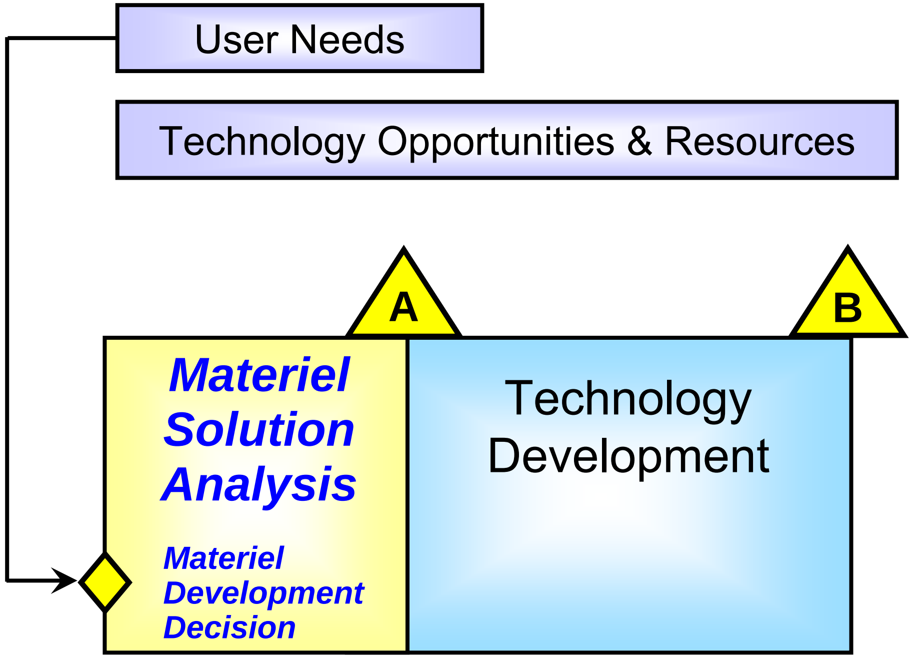
- *The Materiel Development Decision precedes entry into any phase of the acquisition management system*
- *Entrance Criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*



PDR: Preliminary Design Review
CDR: Critical Design Review
FRP: Full Rate Production

IOC: Initial Operational Capability
FOC: Full Operational Capability

Pre-Systems Acquisition



User Need

- **JCIDS Capabilities-Based Assessment (CBA)**
- **Initial Capabilities Document (ICD)**

Technology Opportunities

- ***All sources foreign & domestic***
- ***Small Business Innovation Research (SBIR) Program***
- ***Technology Projects**: **JCTDs, Coalition Warfare Program, Defense Acquisition Challenge Program, etc…***

New terms/requirements in *bold blue italics*

Materiel Development Decision (MDD)

MDA:

- ***Approves AoA Study Guidance***
- ***Determines acquisition phase of entry***
- ***Identifies initial review milestone***
- Designates Lead DoD Component
- Approves Acquisition Decision Memorandum(ADM)

Regulatory Requirements

•Initial Capabilities Document (ICD)
•***AoA Study Guidance (AoA Plan due immediately following the MDD)***

New terms/requirements in *bold blue italics*

Materiel Solution Analysis

Purpose: ***Assess potential materiel solutions***

- **Enter**: Approved ICD and study guidance for conducting AoA.
- **Activities:** Conduct AoA, develop Technology Development Strategy (TDS) & ***draft CDD***
- **Guided by**: ICD and AoA Plan
- **Exit**: ***AoA completed, materiel solution options for the capability need identified in ICD have been recommended by lead Component conducting AoA***, and phase-specific entrance criteria for the initial review milestone have been satisfied

New terms/requirements in *bold blue italics*

MDA Certification
Prior to Milestone A Approval

Certification Required by 10 USC 2366a:

- *The program fulfills an approved initial capabilities document;*
- *The program is being executed by an entity with a relevant core competency as identified by the Secretary of Defense under section 118b of Title 10, U.S. Code;* ***[see note]***
- *A cost estimate for the program has been submitted and that the level of resources required to develop and procure the program is consistent with the priority level assigned by the JROC*

[and if the program duplicates a capability already provided by an existing system:

- *The duplication of capability provided by this program and the existing system is necessary and appropriate*]

Note: during the period prior to the completion of the first roles and missions review required by section 118b of title 10, United States Code, the certification required by that section shall be that the system is being executed by an entity with a relevant core competency as identified by the Secretary of Defense. (NDAA FY 2009)

Milestone A

MDA approves:

- ***Materiel solution***
- Technology Development Strategy (TDS)
- Exit criteria for next phase
- ***Milestone A Certification (10 USC 2366a)***
- Acquisition Decision Memorandum (ADM)

Statutory & Regulatory Requirements

•Acquisition Decision Memorandum (ADM) •Analysis of Alternatives (AoA) •Acquisition Information Assurance Strategy •Clinger-Cohen Act (CCA) Compliance •CIO Confirmation of CCA Compliance ***(for MDAPs & MAIS, DoD CIO confirms)*** •Consideration of Technology Issues •***Component Cost Estimate (CCE)*** •Economic Analysis (MAIS) •Exit Criteria	•Initial Capabilities Document (ICD) •***Item Unique Identification (IUID) Implementation Plan*** •***Life Cycle Signature Support Plan*** •Market Research •***MDA Program Certification*** •Program Protection Plan (PPP) •***Systems Engineering Plan (SEP)*** •Technology Development Strategy (TDS) •Test & Evaluation Strategy (TES)

New terms/requirements in *bold blue italics*

Technology Development

Purpose: Reduce Technology Risk**, determine *and mature* appropriate set of technologies to be integrated into a full system, *and to demonstrate Critical Technology Elements on Prototypes.***

Enter: MDA ***approved materiel solution*** and TDS**;** ***funding for TD phase activities***

Activities: ***Competitive prototyping; Develop RAM strategy; conduct Preliminary Design Review (PDR)***

Guided by: ICD & TDS ***and supported by SE planning***

Exit: Affordable increment of military-useful capability identified; technology demonstrated in relevant environment; manufacturing risks identified**;** system or increment ready for production within short time frame (normally less than 5 years ***for weapon systems*****)**

New terms/requirements in *bold blue italics*

MDA Certification Prior to Milestone B Approval

Certification Required by 10 USC 2366b:

I have received the program business case analysis for the (name of program) and certify on the basis of the analysis that:

- The program is affordable when considering the ability of the Department of Defense to accomplish the program's mission using alternative systems;
- The program is affordable when considering the per unit cost and the total acquisition cost in the context of the total resources available during the period covered by the future-years defense program submitted during the fiscal year in which the certification is made;
- Reasonable cost and schedule estimates have been developed to execute the product development plan under the program; and
- Funding is available to execute the product development and production plan under the program, through the period covered by the future-years defense program submitted during the fiscal year in which the certification is made, consistent with the estimates above.

I further certify that:

- Appropriate market research has been conducted prior to technology development to reduce duplication of existing technology and products;
- The Department of Defense has completed an analysis of alternatives with respect to the program;
- The Joint Requirements Oversight Council has accomplished its duties with respect to the program pursuant to section 18l(b) of title 10, United States Code, including an analysis of the operational requirements for the program;
- The technology in the program has been demonstrated in a relevant environment;
- The program demonstrates a high likelihood of accomplishing its intended mission; and
- The program complies with all relevant policies, regulations, and directives of the Department of Defense

Milestone B

MDA approves:

- Program Initiation (for most programs)
- Entry into ***EMD***
- Acquisition Strategy
- Acquisition Program Baseline
- LRIP quantities
- Exit criteria for next phase
- ***Type of Contract***
- ***Milestone B Certification (10 USC 2366b)***
- ADM

New terms/requirements in *bold blue italics*

Engineering & Manufacturing Development

Purpose: Develop a system or increment of capability, develop an affordable manufacturing process, ***minimize logistics footprint***

B

C

Engineering and Manufacturing Development

Integrated System Design

System Capability & Manufacturing Process Demonstration

Post PDR Assessment

Post CDR Assessment

- **Enter:** Mature Technology; Approved Requirements; Full Funding in FYDP
- **Activities:** ***Define System of System Functionality & Interfaces***, Complete Detailed Design**,** ***System-Level PDR (as needed)/CDR, Establish Product Baseline,***
- **Guided by:** **CDD,** ***Acq Strategy, SEP & TEMP***
- **Exit:** ***Complete System-Level CDR and Post-CDR Assessments by MDA***

- **Enter:** ***Post-CDR Assessment and Establishment of initial Product Baseline***
- **Activities:** Developmental Testing (DT) Assesses Progress Against Technical Parameters, and Operational Assessments (OA) Against CDD
- **Guided by:** **CDD,** ***Acq Strategy, SEP & TEMP***
- **Exit:** System Demonstrated in Intended Environment using ***production-representative articles; Manufacturing Processes Demonstrated*****;** Meets Exit Criteria and MS C Entrance Requirements

Milestone B: Statutory and Regulatory Requirements

All programs except where noted (see encl. 4, DoDI 500.02)

- Acquisition Decision Memorandum (ADM)
- Analysis of Alternatives (AoA) (update)
- Acquisition Strategy
- Affordability Assessment
- Acquisition Program Baseline
- Acquisition Information Assurance Strategy
- ***Alternate Live Fire T&E Plan***
- Benefit Analysis & Determination
- Capability Development Document (CDD)
- Clinger-Cohen Act (CCA) Compliance
- CIO Confirmation of CCA Compliance ***(for MDAPs & MAIS, DoD CIO confirms)***
- Consideration of Technology Issues (ACAT I & II)
- Competition Analysis
- ***Component Cost Estimate (CCE) (MAIS)***
- Cooperative Opportunities
- Core Logistics Analysis/Source of Repair Analysis
- Cost Analysis Requirements Description (CARD) (MDAP & MAIS)
- ***Corrosion Prevention Control Plan***
- ***Data Management Strategy (in acquisition strategy)***
- Economic Analysis (MAIS)
- Exit Criteria
- Initial Capabilities Document (ICD)
- Independent Cost Estimate (ACAT I)
- Independent Technology Readiness Assessment (TRA) (ACAT ID)
- Information Support Plan (ISP)
- Industrial Base Capabilities (MDAP)
- ***Item Unique Identification Impl Plan (SEP annex)***
- Live Fire T&E Waiver
- Life Cycle Sustainment Plan (LCSP)
- ***Life Cycle Signature Support Plan***
- LRIP Quantities (ACAT I & II)
- Manpower Estimate (MDAP)
- Market Research
- ***MDA Program Certification***
- ***MDA Assessment of compliance with Chemical, Biological, Radiological, and Nuclear Survivability Requirements (Not in Encl 4)***
- Net-Centric Data Strategy (in ISP)
- Operational Test Agency OT&E Report
- ***Preliminary Design Review Report***
- Program Protection Plan (PPP)
- Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)***Replaced System Sustainment Plan (MDAP)***
- Selected Acquisition Report (SAR) (MDAP)
- Spectrum Supportability Determination
- ***Systems Engineering Plan (SEP)***
- ***System Threat Assessment Report (STAR)(ACAT I)***
- System Threat Assessment (ACAT II)
- Technology Readiness Assessment (TRA)
- Test & Evaluation Master Plan (TEMP)

New terms/requirements in *bold blue italics*

Milestone C

MDA Approves:

- Updated Acquisition Strategy and Acquisition Program Baseline
- Entry into LRIP for systems that require a LRIP, into production or procurement for systems that do not require LRIP, or into limited deployment for MAIS programs or software intensive systems with no production components
- Exit criteria for LRIP if appropriate
- Acquisition Decision Memorandum

Production & Deployment

C

Purpose: Achieve an operational Capability that satisfies mission needs

Production & Deployment

LRIP/IOT&E

FRP Decision Review

Full-Rate Production & Deployment

- **Enter:** Acceptable performance in DT & OA; mature software; no significant manufacturing risks; approved CPD**;** ***refined integrated architecture*****;** acceptable interoperability and operational supportability; demonstration of affordability; fully funded; phased for rapid deployment.
- **Activities:** IOT&E, LFT&E and Interoperability Testing of Production or Production-Representative Articles; ***IOC possible***
- **Guided by:** CPD, TEMP
- **Exit:** System Operationally Effective, Suitable and Ready for Full-Rate Production

- **Enter:** Beyond LRIP & LFT&E Reports (OSD T&E/LFT&E programs) Submitted to Congress
- **Activities:** Full-Rate Production; Fielding and Support of Fielded Systems; IOC/FOC
- **Guided by:** Acq Strategy & Life Cycle Sustainment Plan
- **Exit:** Full Operational Capability; Deployment Complete

New terms/requirements in *bold blue italics*

Milestone C: Statutory and Regulatory Requirements

All programs except where noted (see encl. 4, DoDI 5000.02)

- Acquisition Decision Memorandum (ADM)
- Analysis of Alternatives (AoA) (update)
- Acquisition Strategy
- Affordability Assessment
- Acquisition Program Baseline
- Acquisition Information Assurance Strategy
- Benefit Analysis & Determination
- Capability Production Document (CPD)
- Title 40/Clinger-Cohen Act (CCA) Compliance
- CIO Confirmation of CCA Compliance ***(for MDAPs & MAIS, DoD CIO confirms)***
- Consideration of Technology Issues (ACAT I & II)
- Competition Analysis
- ***Component Cost Estimate (CCE)***
- Cooperative Opportunities
- Core Logistics Analysis/Source of Repair Analysis
- Cost Analysis Requirements Description (CARD) (MDAP & MAIS)
- ***Corrosion Prevention Control Plan***
- ***Data Management Strategy (in acquisition strategy)***
- Exit Criteria
- Initial Capabilities Document (ICD) (if program initiation)
- Independent Cost Estimate (ACAT I)
- Independent Technology Readiness Assessment (TRA) (ACAT ID)
- Information Support Plan (ISP)
- Industrial Base Capabilities (MDAP)
- ***Item Unique Identification Plan (SEP annex)***
- Life Cycle Sustainment Plan (LCSP)
- ***Life Cycle Signature Support Plan***
- Manpower Estimate (MDAP)
- MDA Program Certification (if program initiation)
- ***Military equipment valuation (in acquisition strategy)***
- Net-Centric Data Strategy (in ISP)
- Operational Test Agency OT&E Report
- Program Protection Plan (PPP)
- Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE)
- Selected Acquisition Report (SAR) MDAP (if rebaselined)
- Spectrum Supportability Determination
- ***Systems Engineering Plan (SEP)***
- ***System Threat Assessment Report (STAR)(ACAT I)***
- System Threat Assessment (ACAT II)
- Technology Readiness Assessment (TRA)
- Test & Evaluation Master Plan (TEMP)

New terms/requirements in *bold blue italics*

Full Rate Production Decision Review (FRPDR)

MDA Approves:

- Full-rate production
- Updated Acquisition Strategy
- Updated Acquisition Program Baseline
- Exit criteria, if appropriate
- Provisions for evaluation for post-deployment performance
- Acquisition Decision Memorandum (ADM)

FRPDR Statutory and Regulatory Requirements

•Acquisition Decision Memorandum (ADM) •Analysis of Alternatives (AoA) (AIS only) •Acquisition Strategy •Acquisition Program Baseline •Acquisition Information Assurance Strategy •Beyond LRIP Report (DOT&E T&E Oversight Programs) •Clinger-Cohen Act (CCA) Compliance •Confirmation of CCA Compliance ***(for MDAPs & MAIS, DoD CIO confirms)*** ***•Component Cost Estimate (CCE)*** •Cost Analysis Requirements Description (CARD) (MDAP & MAIS) ***•Data Management Strategy (part of Acq Strategy)*** •Economic Analysis	•Exit Criteria •IT and NSS Joint Interoperability Test Certification (all IT incl NSS) •IOT&E Completed ACAT I and II (conventional weapons systems for use in combat) •Independent Cost Estimate (ACAT I) (if MDA requests) ***•Life Cycle Sustainment Plan (LCSP)*** •Live Fire T&E Report (OSD LFT&E Programs) •Manpower Estimate (MDAP) ***•Military Equipment Valuation (part of Acq Strategy)*** •Operational Test Agency OT&E Report •Post Implementation Review •Programmatic Environment, Safety, & Occupational Health Evaluation (PESHE) •Test & Evaluation Master Plan (TEMP)

For AIS systems, FRPDR is the Full Deployment Decision Review

New terms/requirements in *bold blue italics*

Operations & Support

Purpose: Execute a support program that meets materiel readiness and operational support performance requirements, and sustains the system in the most cost-effective manner over its total life cycle.

FOC

Operations & Support

Life Cycle Sustainment Disposal

- **Entrance:** Approved CPD; ***approved LCSP; successful FRP Decision***
- **Activities:** ***Performance-Based Life-Cycle Product Support (PBL)*** planning, development, implementation, and management; initiate system modifications as necessary; continuing reviews of sustainment strategies
- **Guided by:** Acquisition Strategy/LCSP

- **Activities:** Demilitarize and Dispose of Systems IAW Legal and Regulatory Requirements, Particularly Environmental Considerations and Explosives Safety
- **Guided by:** Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE)

New terms/requirements in *bold blue italics*

Detailed
Policy Changes

Defense Acquisition University

New Policy Directed by Congress

- Military Equipment Valuation (accounting for military equipment)
- MDA Certification at Milestones A & B
- Cost type contract for EMD Phase requires written determination by MDA
- Lead Systems Integrator Restrictions
- Replaced System Sustainment Plan
- Configuration Steering Boards (CSBs)

New Policy Directed by Congress

Continued…

- New MAIS Reporting Requirements
- “Time-Certain” IT Business Systems Development
- Defense Business Systems Oversight
- MDA assessment of compliance with chemical, biological, radiological, and nuclear survivability (CBRN) requirements at Milestones B and C
- Data Management Strategy

New Policy Directed by Congress

Continued…

- Detailed Acquisition of Services Policy
- Independent management reviews (Peer Reviews) for supplies and services contracts
- Interim Beyond LRIP Report
- DOT&E's Role in Testing Force Protection Equipment / Non-Lethal Weapons
- Nunn-McCurdy breach / APB Revision Procedure
- Cost of energy in AoA and resource estimate

New or Revised Regulatory Policy

- Detailed Systems Engineering Policy
- Program Support Reviews (PSRs)
- Integrated Developmental and Operational Test & Evaluation
- Restricted use of performance requirements that do not support KPPs
- Comparison with current mission capabilities during OT&E
- Assessment of Operational Test Readiness (AOTR)
- Contract Incentives Strategy
- Life-Cycle Sustainment Plan (LCSP)

New or Revised Regulatory Policy

Continued…

- Contracting for Operational Support Services
- Approval of Technology Development Strategy prior to Release of final RFP for Technology Development Phase
- Approval of Acquisition Strategy prior to release of final RFP for EMD or any succeeding phase.
- Reliability, Availability, and Maintainability (RAM) strategy
- Review and Assessment of New or Modified Communications Waveforms.
- ⇨ Evolutionary Acquisition Revised

Defense Acquisition University

Enclosure 4, Table 2-2

Statutory Requirements Added For ACAT II and Below Programs
(unless otherwise noted)

Requirement	Reference	When Required	Comment
Analysis of Alternatives (AoA) – all IT including NSS	40 USC Subtitle III	MS A, B & C	Updated as necessary at MS B and C
Data Management Strategy (ACAT II only)	10 USC 2320	MS B, C & FRPDR	Part of Acq Strategy
LRIP Quantities (ACAT II only)	10 USC 2400	MS B	
Military Equipment Program Valuation	PL 101-576 & Statement of Federal Financial Accounting Standards, No 6.	MS C & FRPDR (or Equiv)	Part of Acq Strategy

Enclosure 4, Table 3

Regulatory Requirements Added/Revised For All Programs

(unless otherwise noted)

Requirement	Reference	When Required	Comment
Acquisition Info Assurance Strategy	DoDI 8580.1	MS A, B, C & FRPDR or FDDR	All IT, Including NSS
Analysis of Alternatives (AoA)	DoDI 5000.02	MS A, B, & C Full Deployment DR for AIS	Updated as necessary at MS B and C
AoA Study Guidance	DoDI 5000.02	MDD	
Component Cost Estimate	DoDI 5000.02	MDAP: MS B & FRPDR MAIS: whenever EA is required	Mandatory for MAIS; optional for MDAP
Corrosion Prevention Control Plan	DoDI 5000.02	MS B & C	Part of Acq Strategy ACAT I only
Life Cycle Sustainment Plan	DoDI 5000.02	MS B, C & FRPDR	Part of Acq Strategy
Life Cycle Signature Support Plan	DoDD 5250.01	MS A, B, & C	

Encl 8, Human Systems Integration, changes

- Mix of military, DoD civilian, and contractor support to operate, maintain and support (including training) system must be determined based on Manpower Mix Criteria and reported in Manpower Estimate
- Economic analyses to support workforce mix decisions must use tools that account for all variable and fixed costs, compensation and non-compensation costs, current and deferred benefits, cash and in-kind benefits
- Details on Environment, Safety and Occupational Health (ESOH) moved to new encl 12, Systems Engineering

Encl 9, Acquisition of Services, changes

- **Planning for acquisition of services must consider:**
  - **Requirements development and management**
  - **Acquisition planning**
  - **Solicitation and contract award**
  - **Risk management**
  - **Contract tracking and oversight**
  - **Performance evaluation**
- **Special procedures for IT services that cost over $500M, all services that cost over $1B, and special interest programs designated by ASD(NII), USD(AT&L) or their designees:**
  - **Senior officials/decision authorities must be notified prior to issuing final solicitation (briefing or written)**
  - **ASD(NII)/DoD CIO notifies USD(AT&L) of any proposed acquisition of IT services over $1B**
  - **Review by ASD(NII)/USD(AT&L) initiates review of acquisition strategy – final RFPs cannot be released until approval.**

Encl 9, Acquisition of Services, changes
Continued...

- Policy extended to services acquired after program achieves Full Operational Capability (FOC), if those services were not subject to previous milestones
- Policy does not apply to R&D activities, or services that are approved part of an acquisition program managed IAW DoDI 5000.02
- Senior Officials and decision authorities may apply policy to R&D services at their discretion
- SAEs are Senior Officials for acquisition of services
- USD(AT&L) is Senior Official for acquisition of services for Components outside of military departments – he may delegate decision authority to commanders/ directors of these components
- Independent management reviews (Peer Reviews) required for contracts of $1B or more

Encl 9, Acquisition of Services, changes

Continued...

Acquisition of Services Categories (Table 9)

Category	Threshold	Decision Authority
Acquisitions > $1B	Any services acquisition with total estimated cost of $1B or more	USD(AT&L) or designee
IT Acquisitions > $500M	IT services with total estimated cost of $500M or more	ASD(NII)/DoD CIO or as designated
Special Interest	Designated by USD(AT&L), ASD(NII)/ DoD CIO, or any Mil Dept Senior Official	USD(AT&L) or Senior Officials
Services Category I	Services estimated to cost $250M or more	Senior Officials or as designated
Services Category II	Services estimated to cost $10M or more, but less than $250M	Senior Officials or as designated
Services Category III	Services estimated to cost more than simplified acq threshold, but less than $10M	Senior Officials or as designated

All dollars in FY 2006 constant year dollars

Encl 10, Program Management, changes

- Requires PMs for ACAT II and other significant non-major programs to be assigned for not less that 3 years.
- Program Management Agreements (PMAs) implemented to establish "contract" between PM and acquisition and resource officials
- Provides that waivers for PM/PEO experience and certifications "should be strictly avoided."
- Provides for USD(AT&L) waiver for PEO's to assume other command responsibilities
- Adds US-ratified materiel international standardization agreements to consideration for international cooperative programs

Encl 11, Management of Business Systems (New)

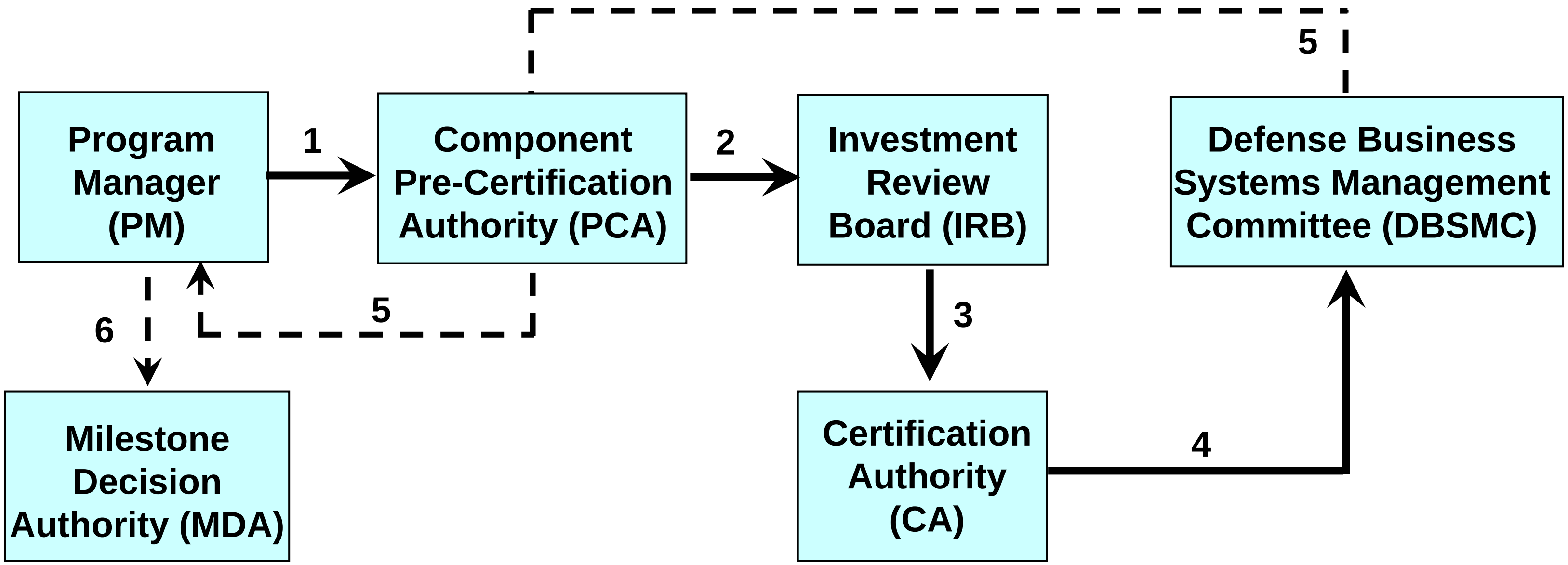
- **Applies to "defense business systems" modernizations with total modernization or development funding exceeding $1 million.**
  - **Defines Defense Business System as an information system, other than a national security system, operated by, for, or on behalf of DoD, including financial management systems, mixed systems, financial data feeder systems, and IT and information assurance infrastructure.**
  - **Defense Business Systems support activities such as acquisition, financial management, logistics, strategic planning and budgeting, installations and environment, and human resource management.**

Encl 11, Management of Business Systems (New), Continued...

- **Funds cannot be expended until the Defense Business System Management Committee (DBSMC) approves Investment Review Board Certification (IRB) that the system:**
  - **Is in compliance with the enterprise architecture; or Is necessary to achieve a critical national security capability or address a critical requirement in an area such as safety or security; or Is necessary to prevent a significant adverse impact on a project that is needed to achieve an essential capability**

Encl 11, Management of Business Systems (New), Continued...

Business Systems Certification and Approval Process



1. PM completes economic viability review & other plans/analysis as requested by the PCA
2. PCA Validates info from PM, forwards certification request to appropriate IRB
3. IRB reviews request, IRB chair recommends appropriate approval authority sign certification memo and request DBSMC approval
4. CA sends signed certification memo to DBSMC for approval
5. DBSMC Chair approves certification and sends decision to the PM through the PCA.
6. PM requests MDA conduct milestone review

Encl 12, Systems Engineering (New)

- Systems Engineering Plan (SEP) required at each milestone
- MDA is approval authority for the SEP
- For programs where USD(AT&L) is MDA, and programs on the DT-only portion of OSD T&E Oversight List, SEPs must be submitted to Director, Systems and Software Engineering 30 days prior to DAB/ITAB review
- PEOs must have lead systems engineer – oversees SE across PEOs portfolio; reviews SEPs; assesses performance of subordinate systems engineers with PEO and PM
- Event-driven technical reviews required – with SMEs independent of program, unless waived by MDA
- Requires configuration management to establish and control product attributes and the technical baseline
- Spectrum Supportability determination required

Encl 12, Systems Engineering (New)

Continued...

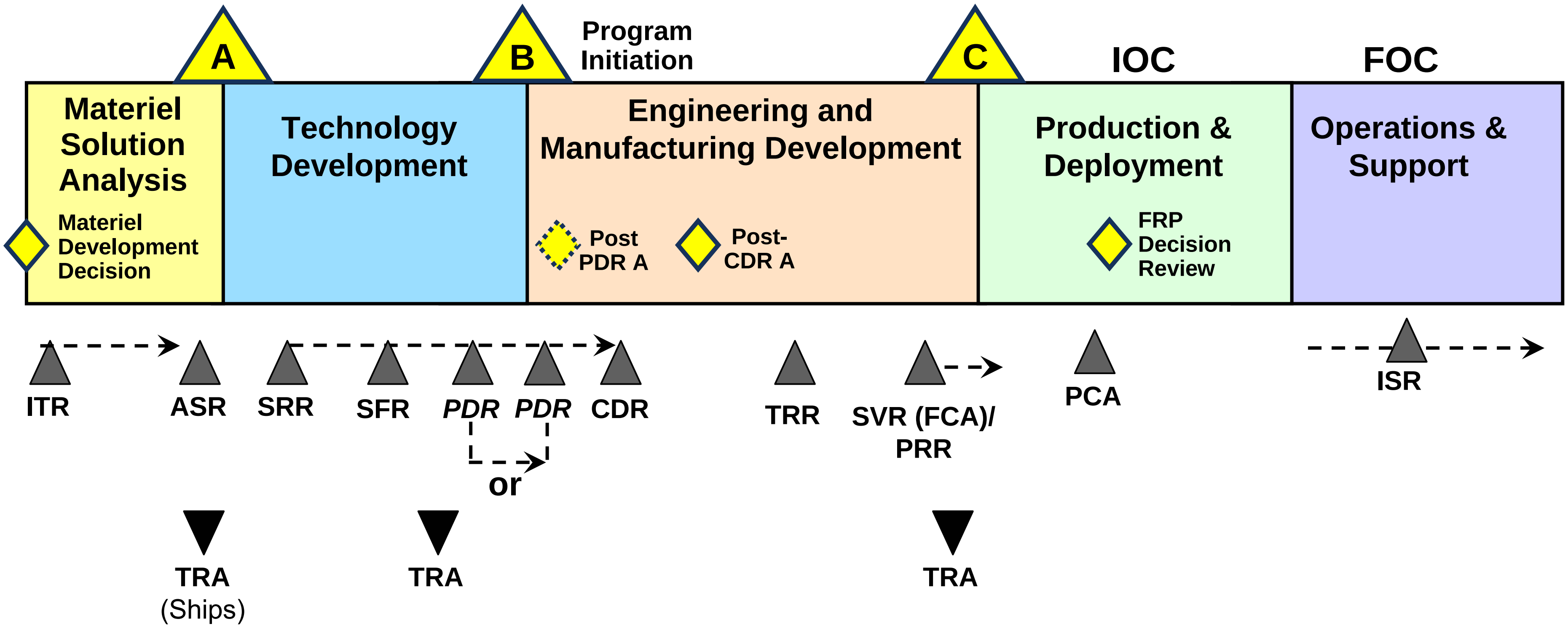
- ESOH risk management required to be integrated with overall SE process; Programmatic ESOH Evaluation (PESHE) required of all programs regardless of ACAT
- NEPA and EO 12114 (Environmental Effects Abroad of Major Federal Actions) analysis required of PM, approved by CAE
- Addresses PM support of Mishap Accident Investigations
- Requires Corrosion Prevention Control Plan for ACAT I programs at MS B and C
- Requires PMs to employ modular open systems approach to design
- Data Management Strategy (DMS) required to assess long-term technical data needs of the system – included in Acquisition Strategy

The Acquisition Warrior

Questions?

Backups

Systems Engineering Technical Reviews



- Initial Technical Review (ITR)
- Alternative Systems Review (ASR)
- Systems Requirements Review (SRR)
- System Functional Review (SFR)
- Preliminary Design Review (PDR)
- Critical Design Review (CDR)
- Post-PDR Assessment (Post-PDRA)
- Post-CDR Assessment (PCDRA)
- Test Readiness Review (TRR)
- System Verification Review (SVR)
- Functional Configuration Audit (FCA)
- Production Readiness Review (PDR)
- Operational Test Readiness Review (OTRR)
- Physical Configuration Audit (PCA)
- Technology Readiness Assessment (TRA)
- In-Service Review (ISR)

Technology and Manufacturing Readiness

A		B		C	IOC	FOC
Materiel Solution Analysis **Materiel Development Decision**	**TECHNOLOGY DEVELOPMENT**	**Engineering & Manufacturing Development** **Post CDR Assessment**	**PRODUCTION & DEPLOYMENT** **FRP Decision Review**	**OPERATIONS & SUPPORT**		

TRLs 1-3 Analytical/ Experimental Critical Function/ Characteristic Proof of Concept	**TRL 4** Component And/or Breadboard Validation In a Laboratory Environment	**TRL 5** Component And/or Breadboard Validation In a Relevant Environment	**TRL 6** System/ Subsystem Model or Prototype Demonstrated In a Relevant Environment	**TRL 7** System Prototype Demonstrated In an Operational Environment		**TRL 8** Actual System Completed Qualified Through Test and Demonstration	**TRL 9** Actual System "Mission Proven" Through Successful Operations	Technology Readiness Levels Defense Acquisition Guidebook para. 10.5.2
MRLs 1-3 Manufacturing Feasibility Assessed. Concepts defined/ developed	**MRL 4** Capability to produce Technology In Lab Environment. Manufacturing Risks Identified **Manufacturing Cost Drivers Identified**	**MRL 5** Capability to Produce Prototype Components **Cost Model Constructed**	**MRL 6** Capability to Produce System/ Subsystem Prototypes **Detailed Cost Analysis Complete**	**MRL 7** Capability to Produce Systems, Subsystems Or Components in a Production Representative Environment **Cost Model Updated To System Level Unit Cost Reduction Efforts Underway**	**MRL 8** Pilot Line Capability Demonstrated. Ready for LRIP **Engineering Cost Model Validated**	**MRL 9** Low Rate Production Demonstrated. Capability In Place for FRP **LRIP Cost Goals Met Learning Curve Validated**	**MRL 10** Full Rate Production Demonstrated. Lean Production Practices In Place **FRP Unit Cost Goals Met**	Manufacturing Readiness Levels Draft MRA Deskbook May 2008

Section 2366b of Title 10, United States Code, requires certification that: the technology in the program has been demonstrated in a relevant environment to enter Milestone B. [TRL 6]

MK 45 Weapon System

Steven J. Cannon
NSWC/Port Hueneme Division
Louisville Detachment

08 April 09

Agenda

- Patrol Coastal Class Ship Capability Gap
- Solution Overview
- Planned Demonstration Event
- Path Forward
- Additional Features Under Consideration

Patrol Coastal Class Ships

PC Weapon Systems

- Current Configuration
  - MK 38 MOD 1 forward
  - MK 96 AFT (6 ships updated with MK 38 MOD 2)
- Issue/Capability Gap
  - Forward mount not stabilized or optically supported
  - High sea states will not allow crew in the focsle area
    - Loading
    - Operating
    - Maintaining
  - MK 38 MOD 2 not a good candidate due to green water and would be inaccessible, like the MK 38 MOD 1
- Developing requirement for a forward Weapon System
  - Remote controlled with on-mount EOS
  - Out range small arms
  - Optics capable of providing improved operational awareness
  - Weapon light enough to remove and stow below deck during extreme sea-states

Solution

- **MK 38 MOD 2 Program of Record replaces the MK 96 aft Weapon System**
- **Develop a lightweight alternate Weapon System for the forward position**
  - **Install in an alternate location**

MK 38 MOD 2 Installation
Aft Location

MK 45 Weapon System

HSV 2 SWIFT

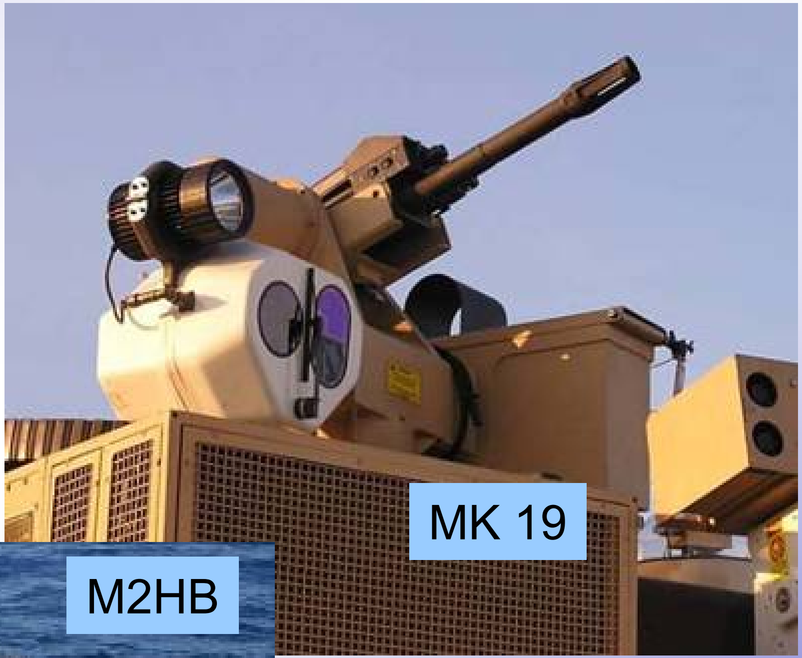
USCG 87’ Patrol Boat
COCHITO

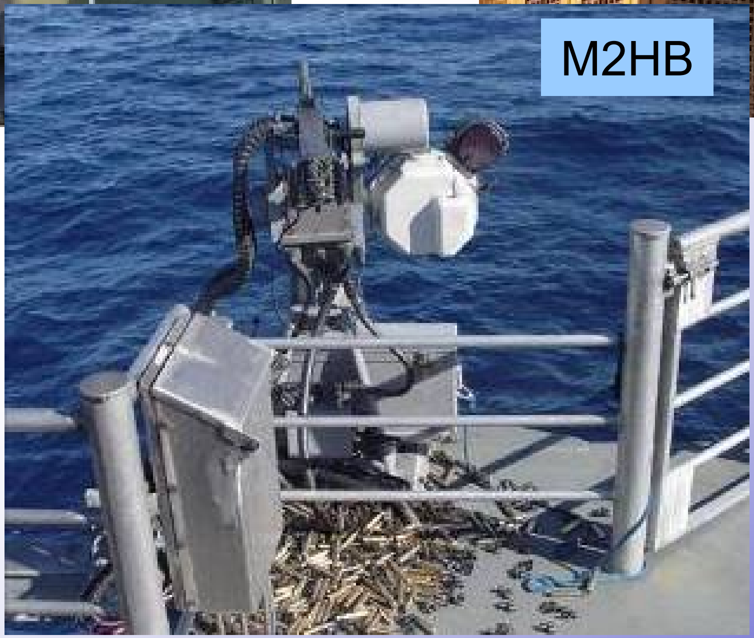
MK 45 Weapon System

- Two axis gyro stabilized
- Remote firing utilizing on-mount optics
- Autotracker
- WSESRB approved for HSV 2 SWIFT

- Cooled FLIR (3-5 micron)
- 2 fixed FOV's (10.8º and 2.2º)
- Day color camera
- Variable zoom (43º to 1.8º)
- 1 Hz eye safe laser rangefinder
- "NightHunter" spotlight
- Optics Wiper/washer

MK 45 w/M240, MK 19, M2HB

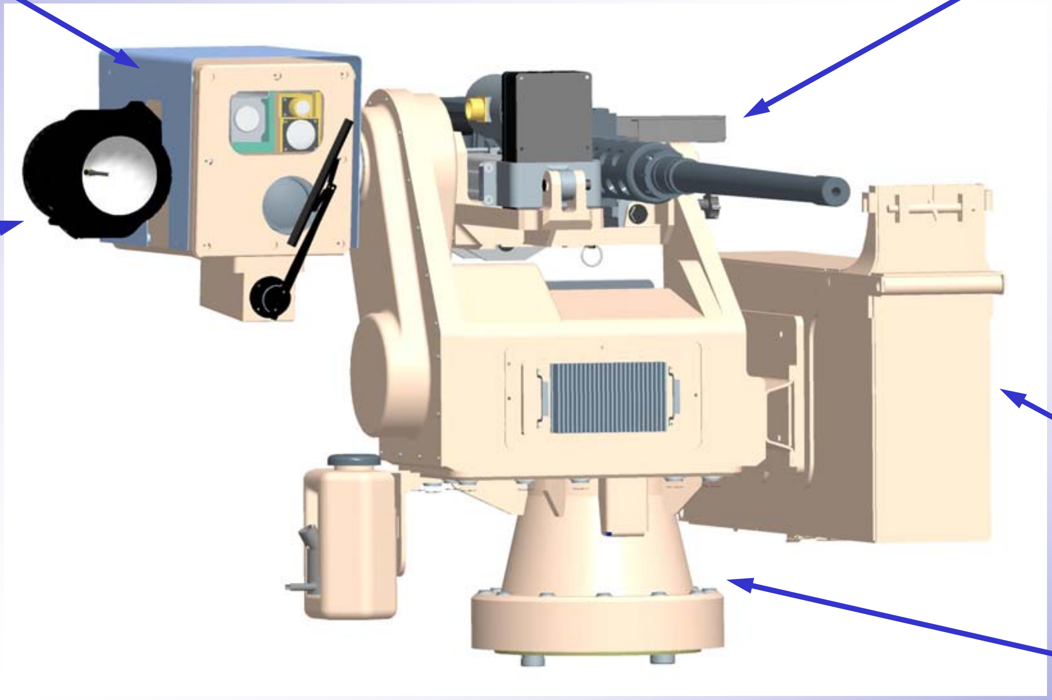




DARPA LW Mount – G Wagon Installation

Naval Expeditionary Overwatch (NEO)

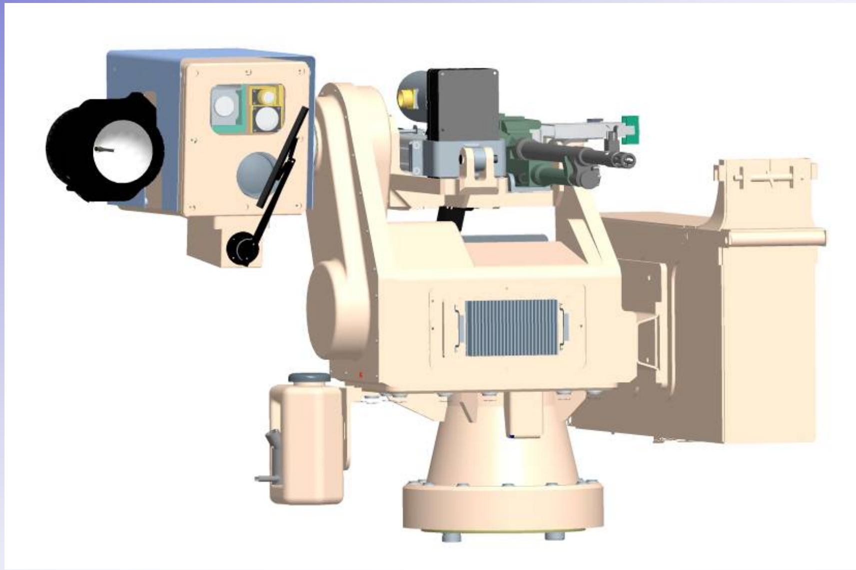
Gunslinger Spiral 3 Mount



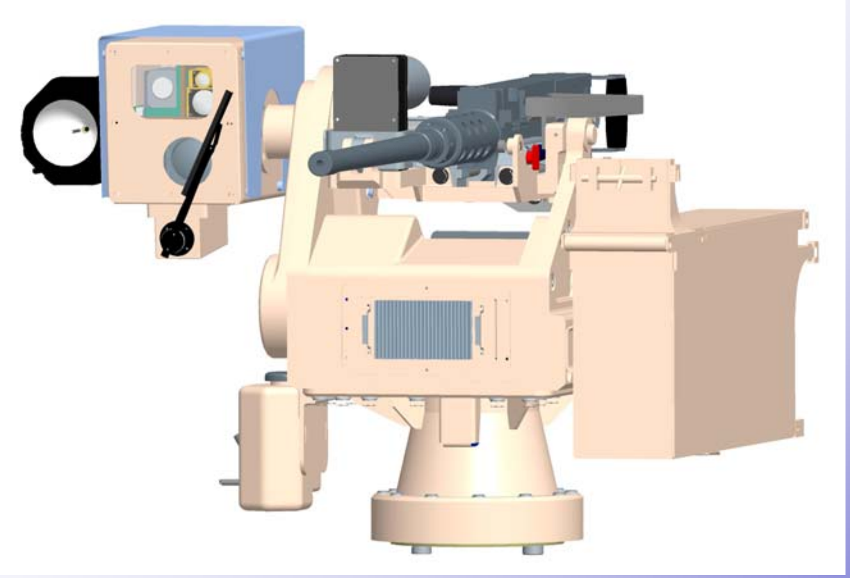
Mount Weight Approx. 265 (No Gun or Ammo)
Overall Dimensions with M2HB = 29.4”H x 38”W x 65.2”D
Working Radius with M2HB = 42.2”

Naval Expeditionary Overwatch (NEO)

Gunslinger Spiral 3 Mount



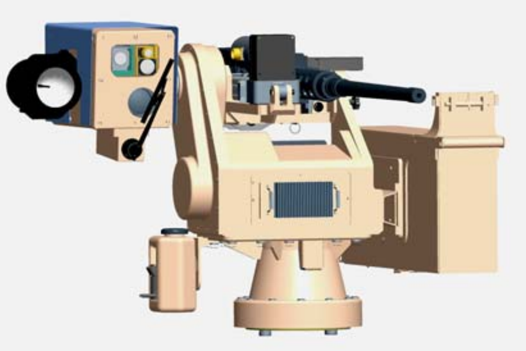
M240 7.62
1,600 Round Capacity



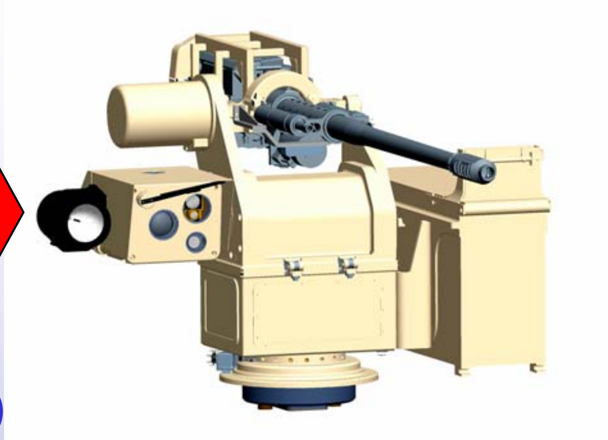
M2HB .50 Cal
400 Round Capacity

Modular Advanced Weapon System (MAWS)

Development

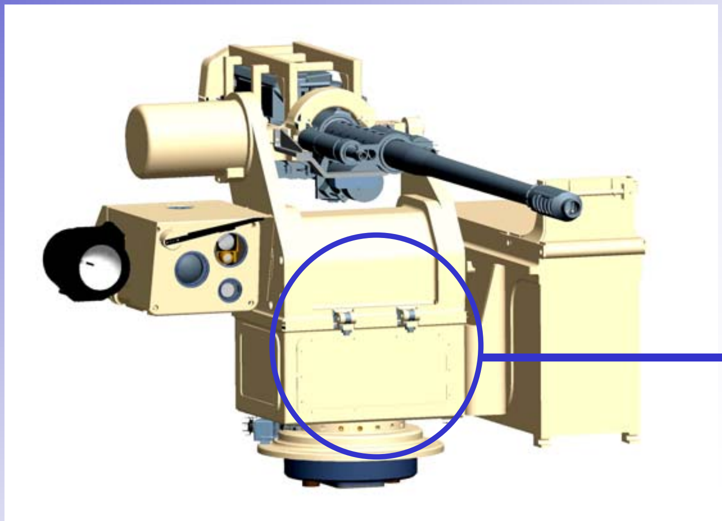


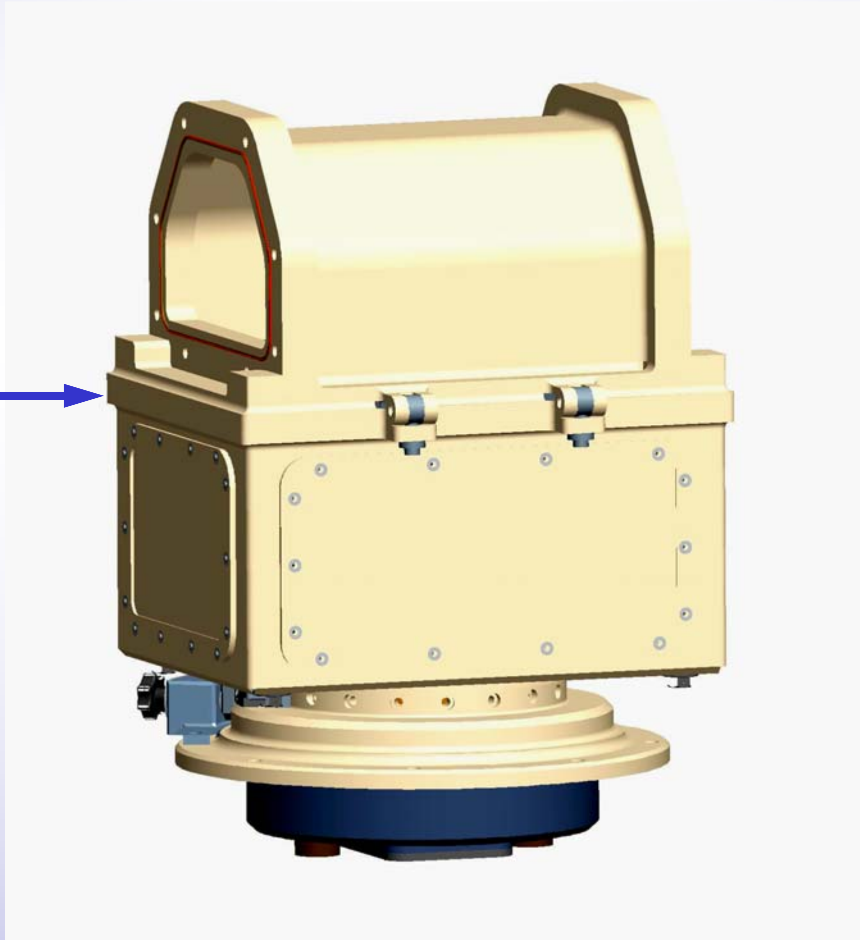
Repackage current MK 45 and MK 45 LW Systems and add new capabilities Into a new Modular Advanced Weapon System (MAWS)



Modular Advanced Weapon System (MAWS)

Common Base Assy



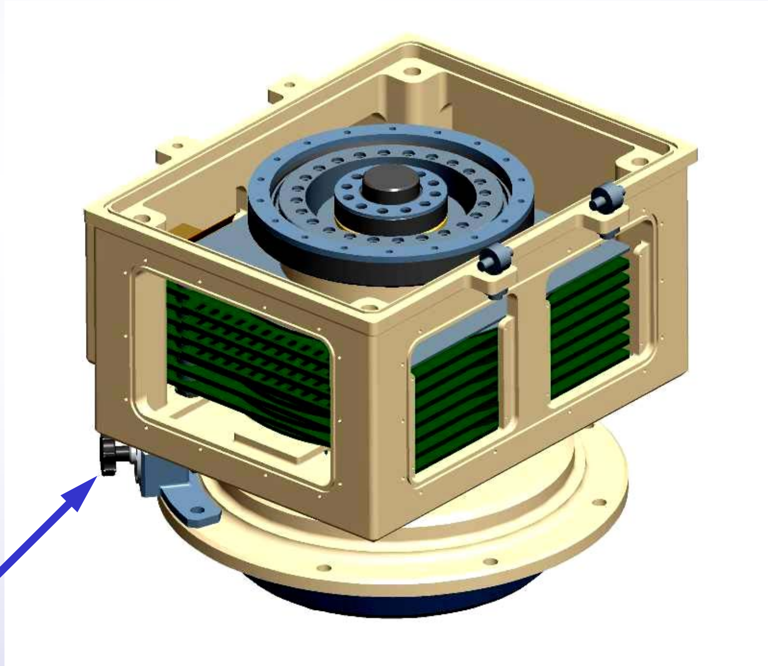


Base Structure Contains:

- Azimuth power drive
- Slip-Ring
- In gimble electronics (Amp Box)

Modular Advanced Weapon System (MAWS)

Integral Slip Ring



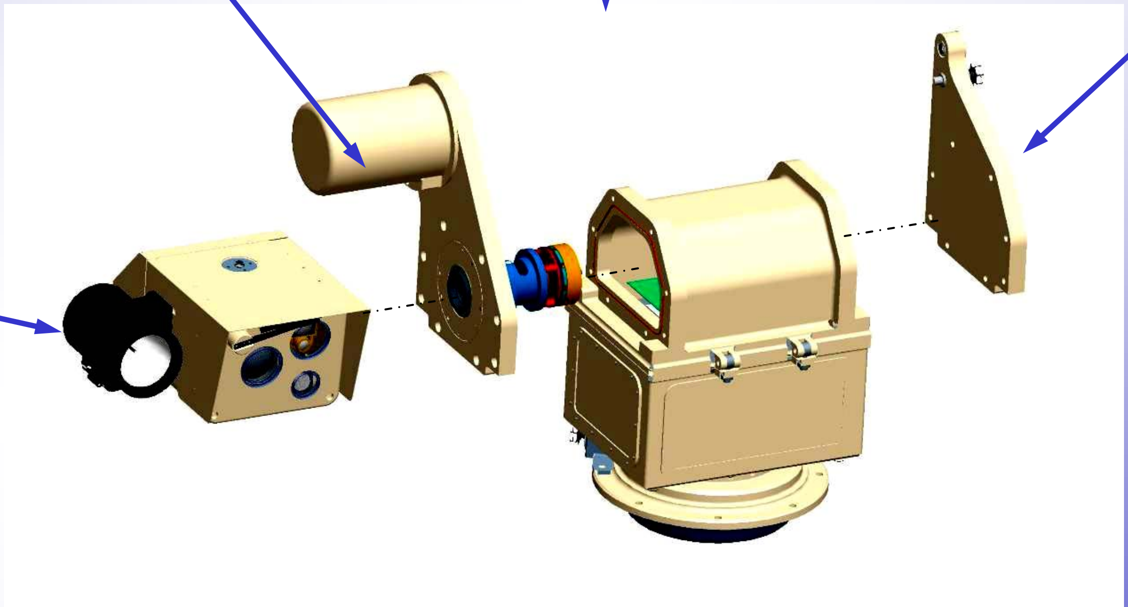
Scaleable slip-ring design allows the addition of circuit paths as needed for payload requirements

Modular Advanced Weapon System (MAWS)

Three Axis Configuration

Three Axis Drive Trunnion Assy contains independent sight and payload drives

Support Trunnion



Sight Assy

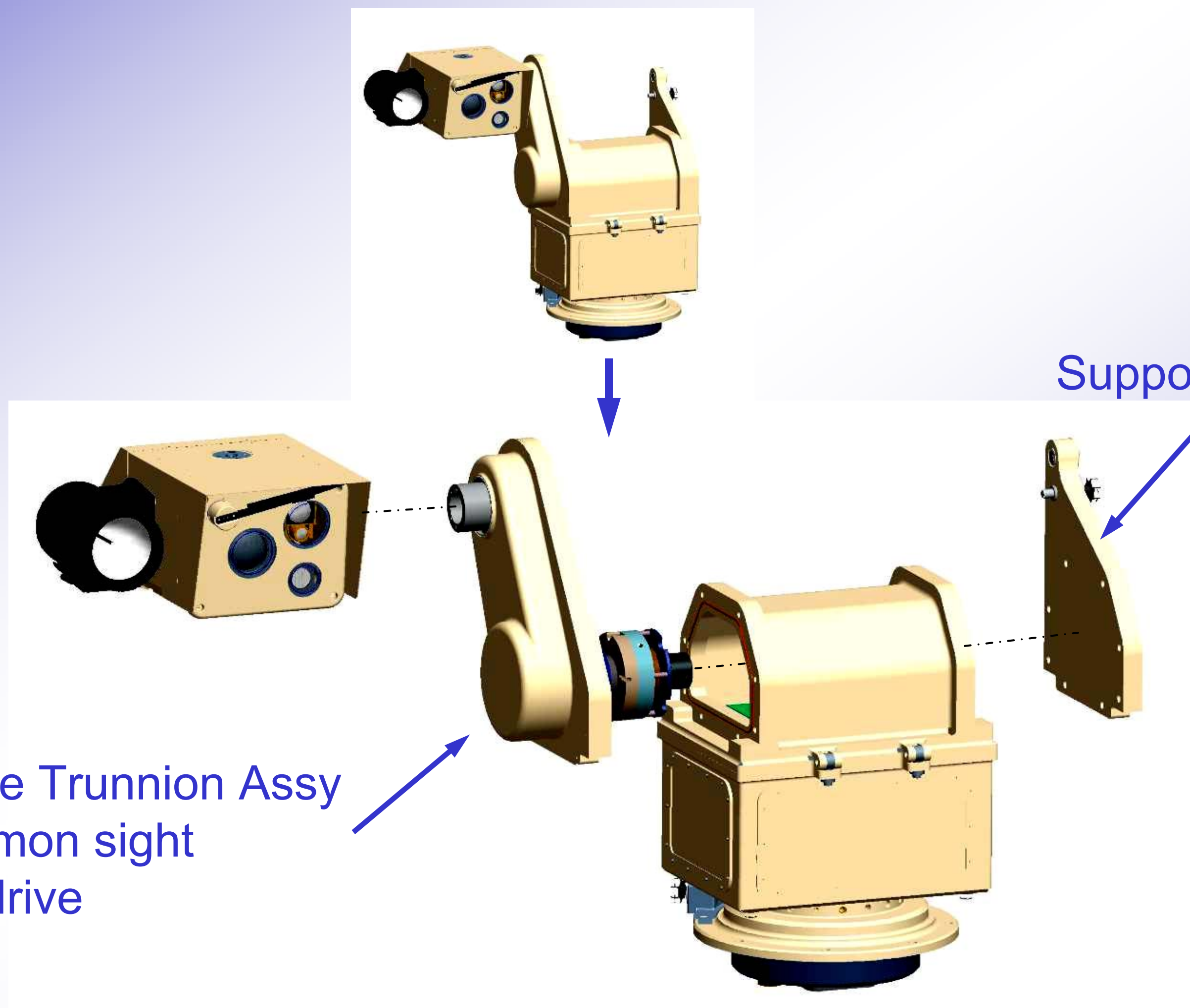
Common Mechanical and Plug and Play Electronic Interfaces

Modular Advanced Weapon System (MAWS)

Two Axis Configuration

Support Trunnion

Sight Assy



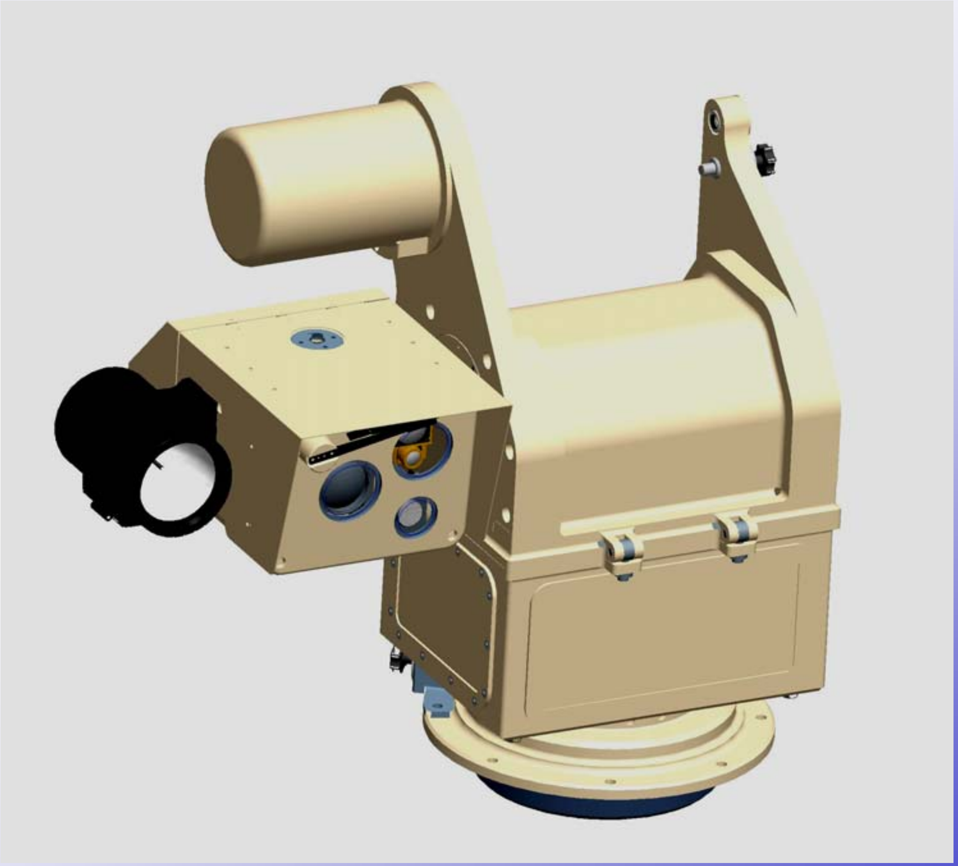
Two Axis Drive Trunnion Assy contains common sight and payload drive

Common Mechanical and Plug and Play Electronic Interfaces

Modular Advanced Weapon System (MAWS)

Sight Interface

- Sight interface has common mechanical and electrical interfaces for plug and play compatibility between sight packages

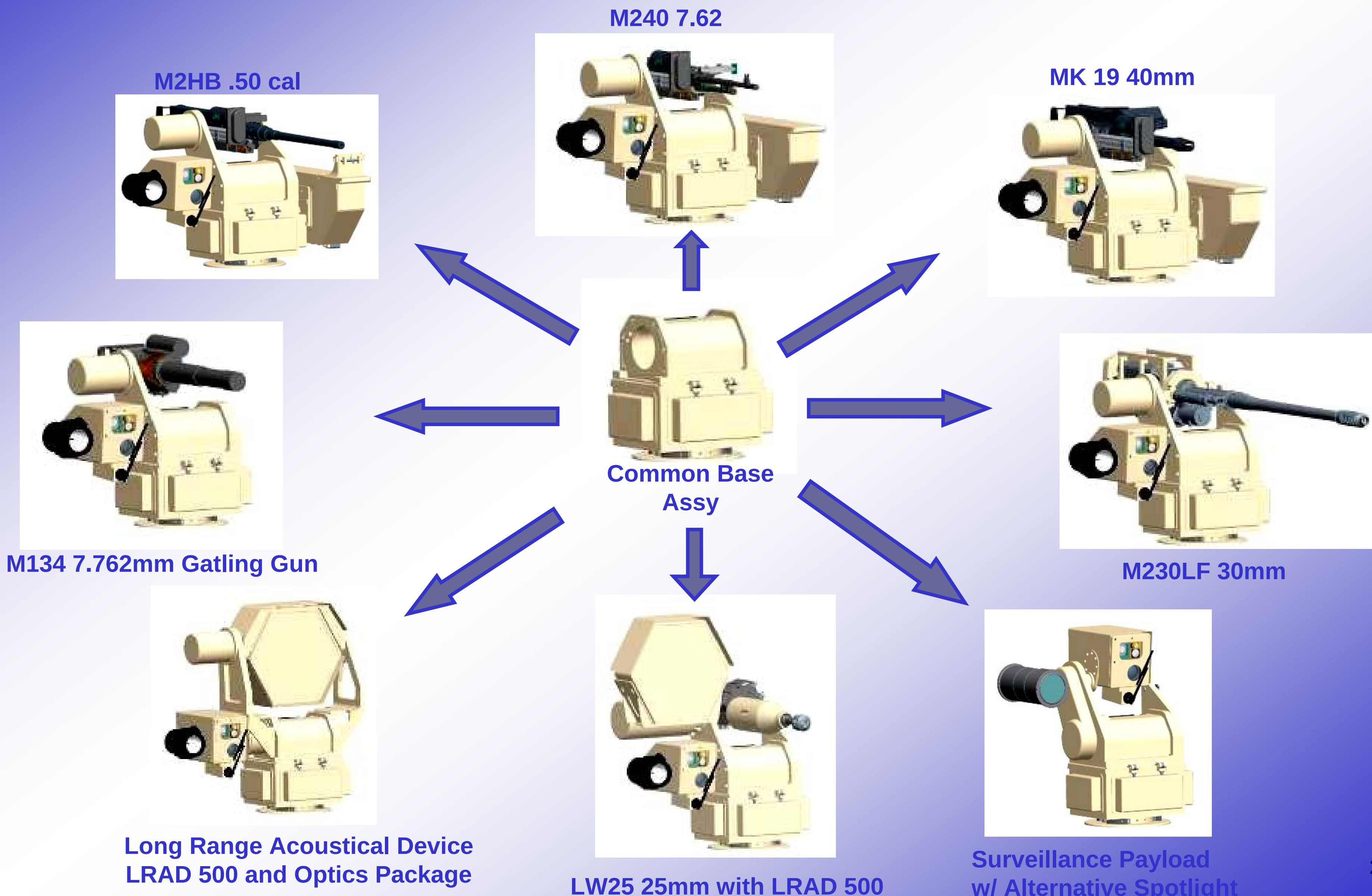


Modular Advanced Weapon System (MAWS)

Principle Concept

- **Modular Advanced Weapon System**
  - **Modular/Scaleable design is adaptable to many payloads and various performance requirements**
  - **Lightweight**
    - **Baseline construction – Aluminum weldments, castings when possible**
    - **Objective – Composite manufacture when possible**
      - **Composite Study Funded**
  - **Cost**
    - **Modular design allows configuration options that satisfy cost/performance requirements**

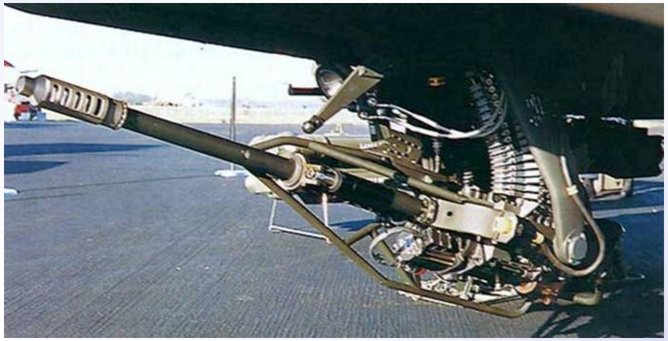
Modular Configurations

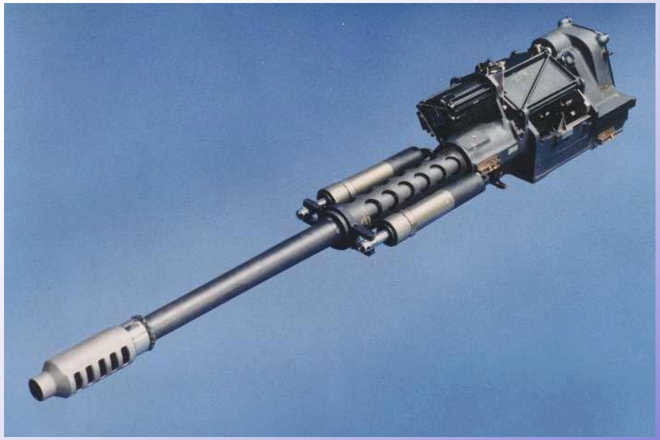


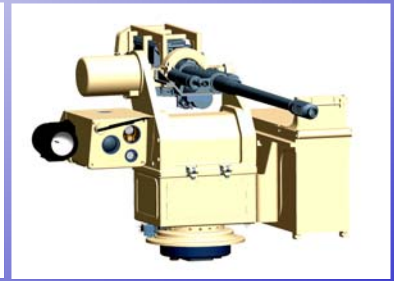
Weapon Choice

M230LF

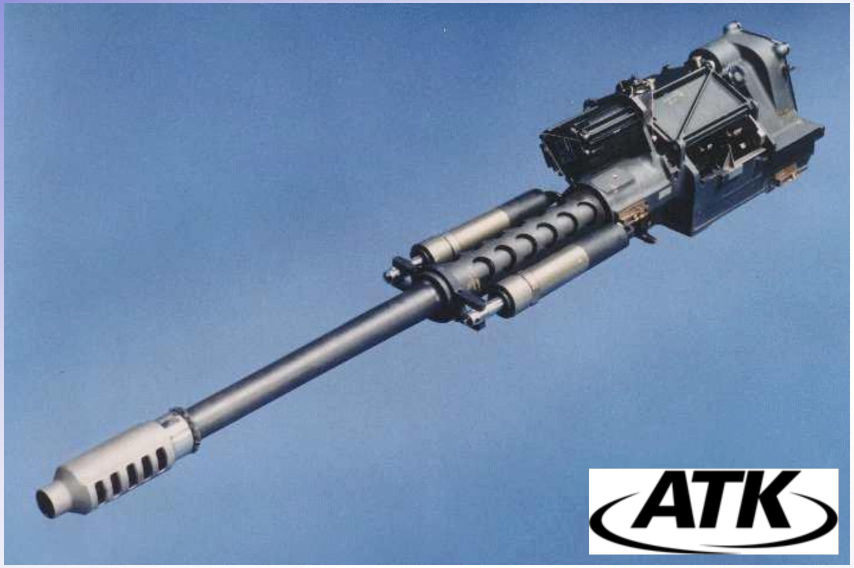
- **Details:**
  - 30mm Chain Gun
  - Effective Range - ~2,500 Yards
  - Lightweight - Approx. 160 lbs
  - Fires electric primed ammunition
  - M230 linkless Chain Gun used on Army AH-64 Apache Helicopter and MH-60 Aircraft
  - M230LF variant being applied to this program is derived from the M230 with the follow modifications:
    - Modified feeder for linked ammunition
    - Added recoil attenuation buffers
    - Percussion firing mechanism – upgrade kit
- **Known Issues:**
  - M230LF Not Type Classified
  - Requires some degree of design finalization by ATK
  - Level of Marinization unknown

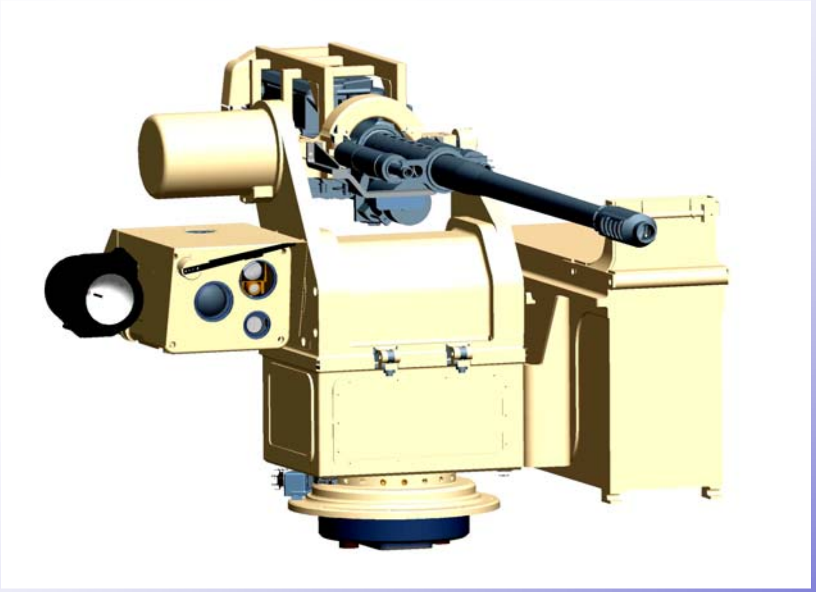






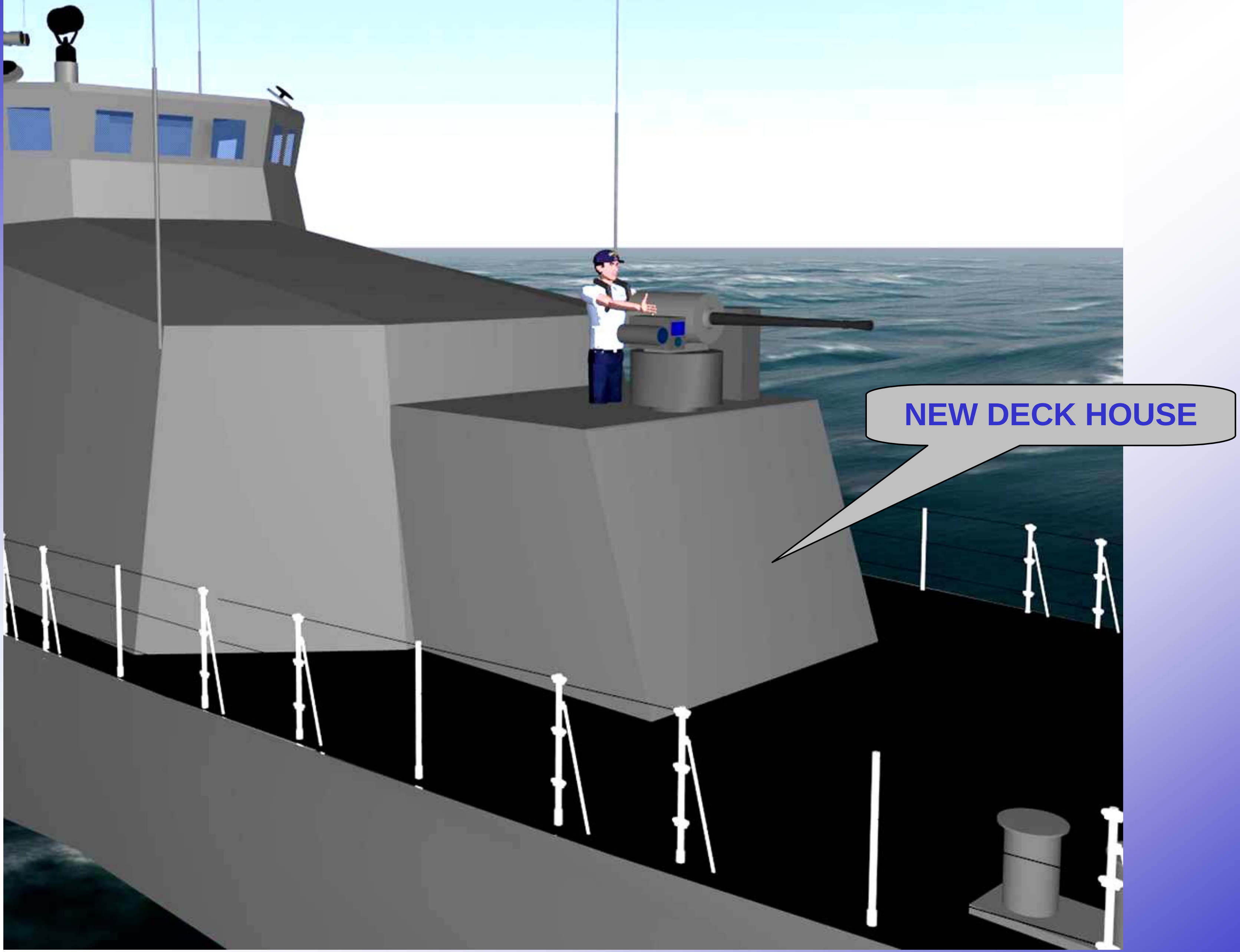
Weapon System Integration



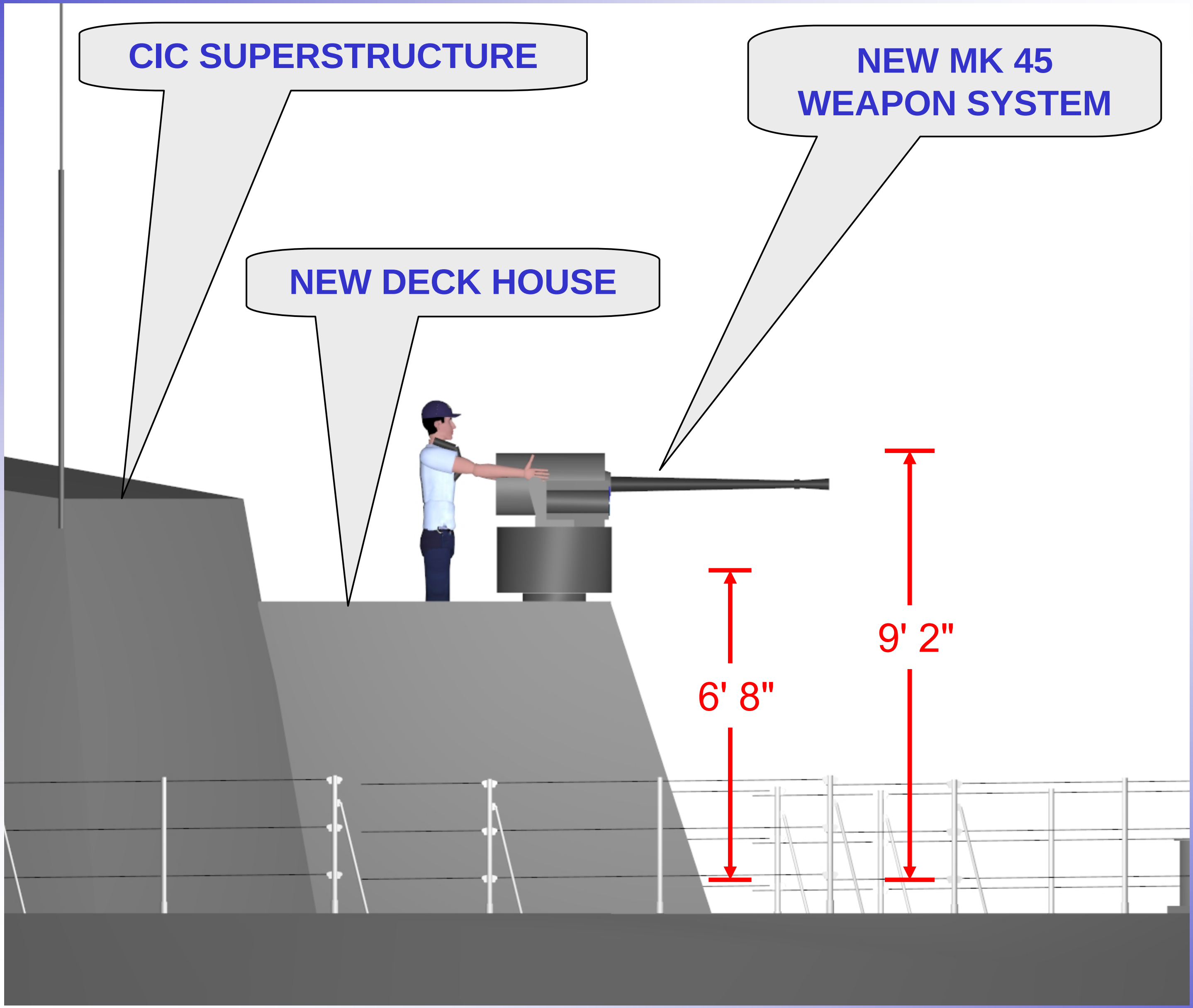


MK 45/MAWS

PC Location Option
for Sept 09 Demonstration

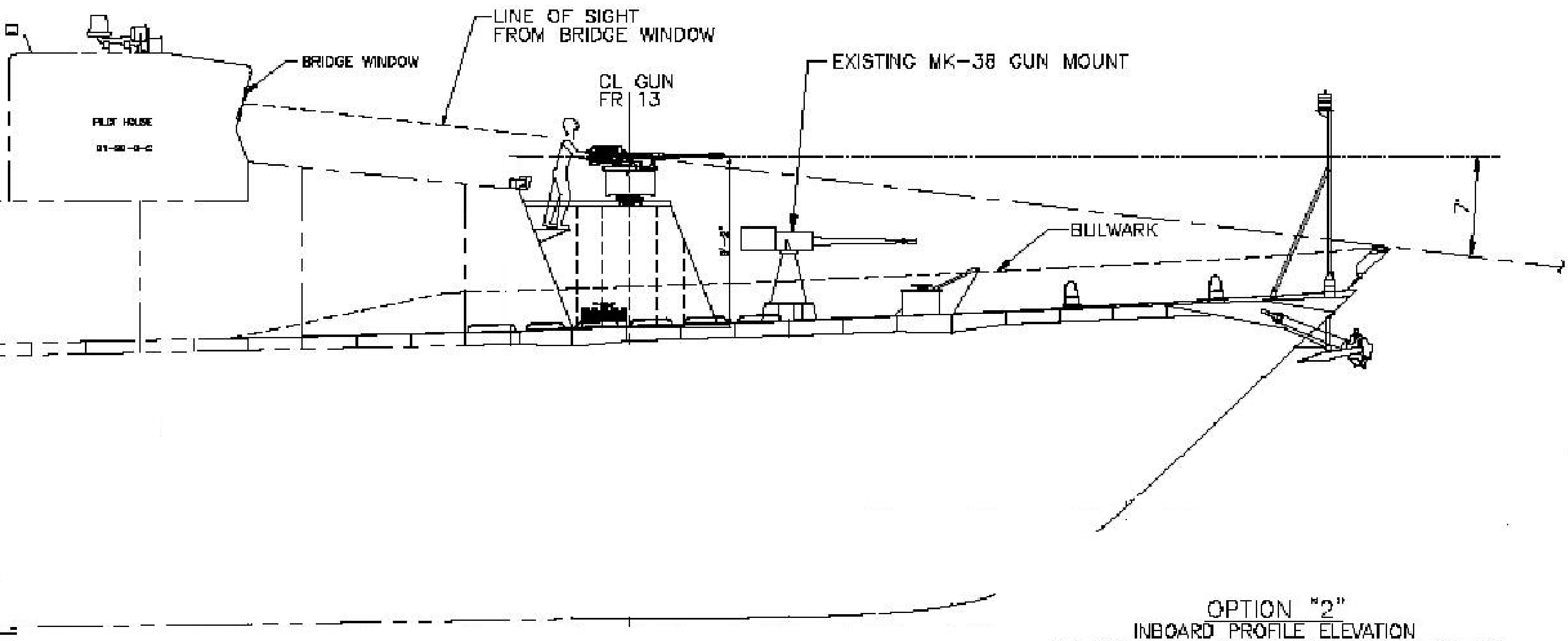


3D MODEL ISOMETRIC VIEW



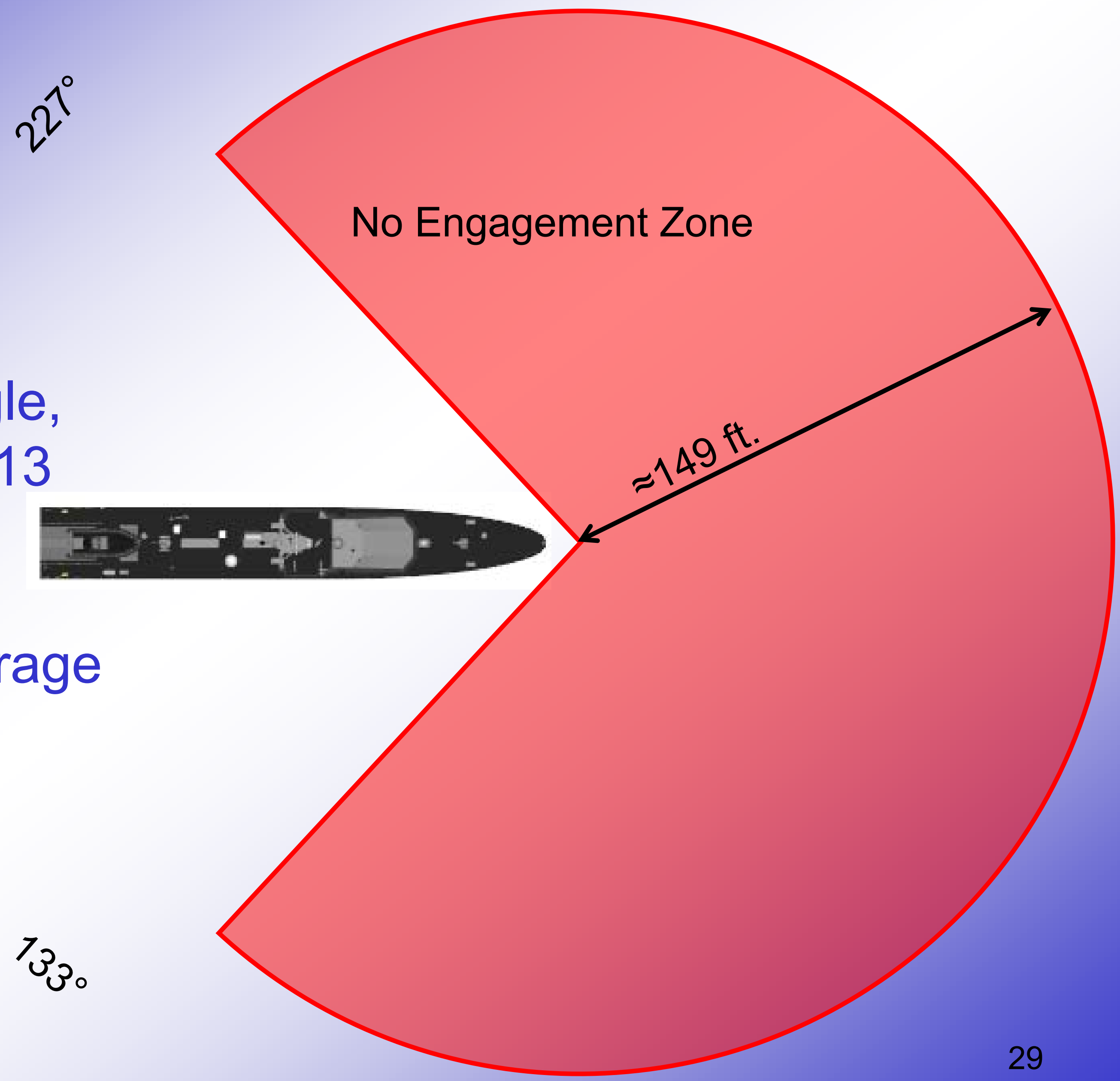
3D MODEL PROFILE VIEW

PILOT HOUSE VIEW



OPTION "2"
INBOARD PROFILE ELEVATION
(N) GUN INSTALLED FWD ELEX RM @ FR 13
W/ NEW PLATF/DK HSE
4" HIGH GUN FOUNDATION

- 7° Depression Angle,
- Located at Frame 13
- Gun Barrel 9' 2" above Main Deck,
- 266° Overall Coverage



Path Forward

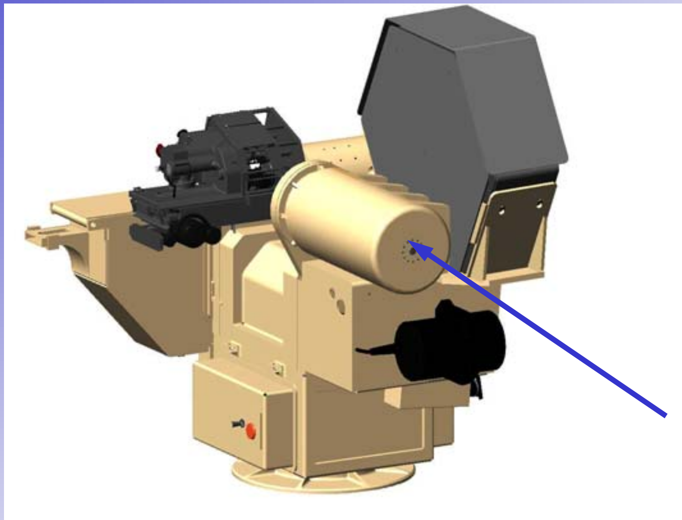
Patrol Coastal At-Sea Demonstration

- Funded by IWS3C, Mr. Kevin LaPointe
- Supported by PCRON, Commodore Coughlin
- Objectives
  - Safely demonstrate the advantages the MK 45 Weapon System
    - Optics
    - Remote operation
    - Stabilization
    - Location improvement
    - Ability for ship's crew to remove and stow the cannon
- Schedule
  - TEMPALT SIDs finalized by 15 May
  - Install TEMPALT 01-24 June 09
  - Install MK 45 31 Aug – 4 Sept 09
  - Demonstration 14-25 Sept 09

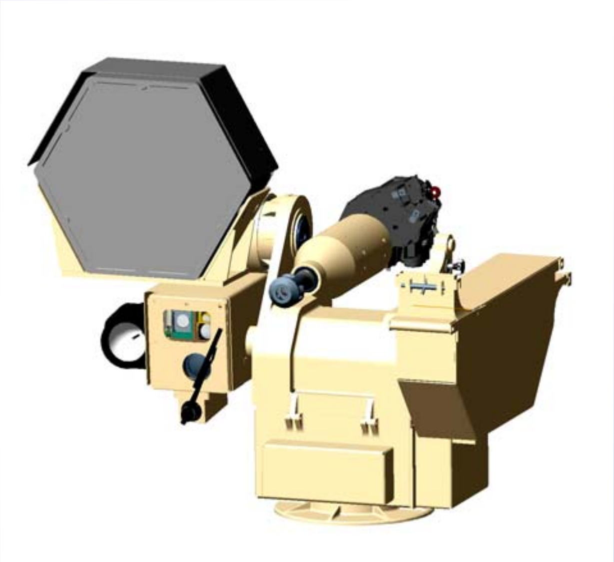
Additional Features Under Consideration

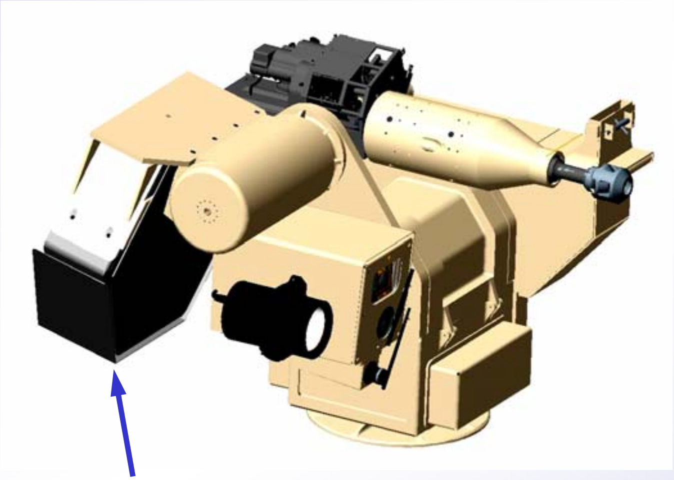
Modular Advanced Weapon System (MAWS)

Auxiliary Drive



Auxiliary Elevation Drive





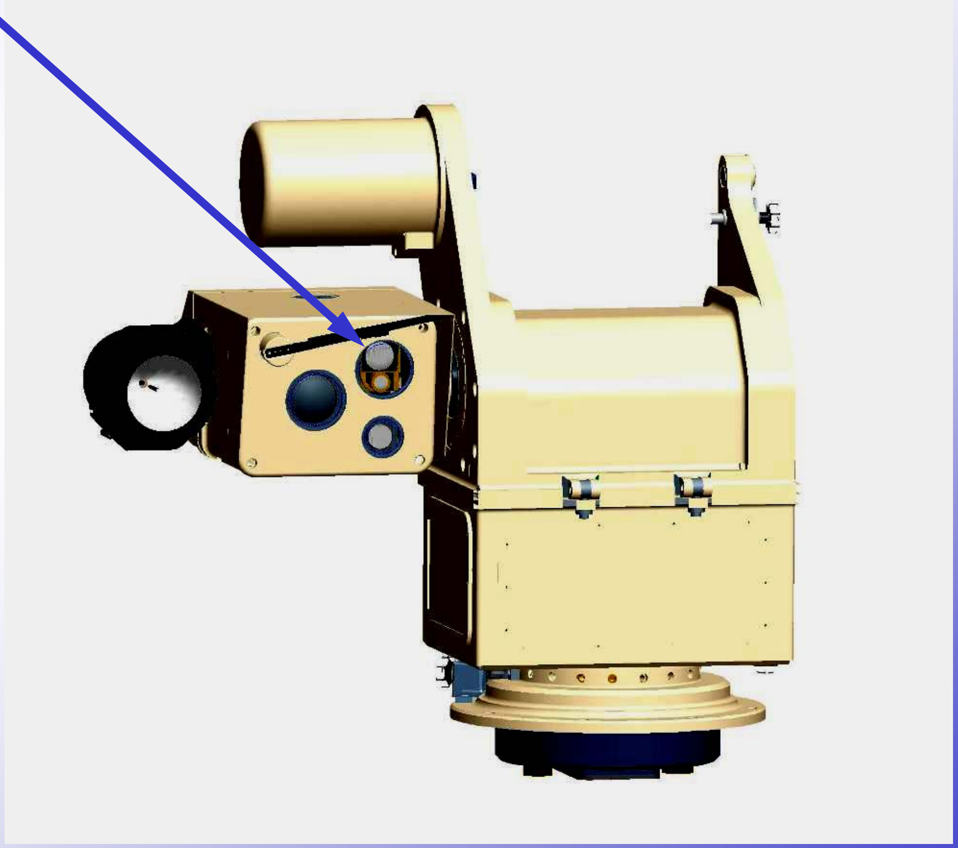
Stowed Position

Proposed configuration for NEO Spiral 2 to support escalation of force initiative

Modular Advanced Weapon System (MAWS)

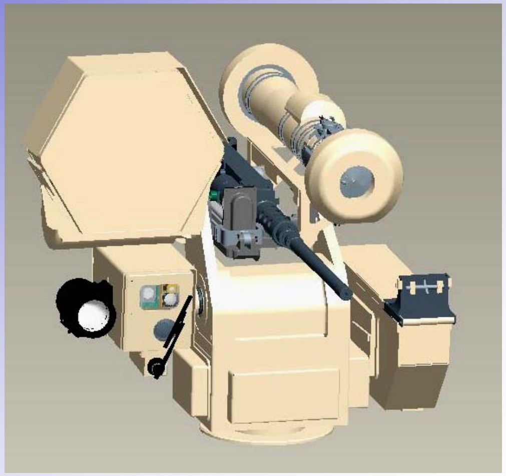
Laser Designator/Sight Improvements

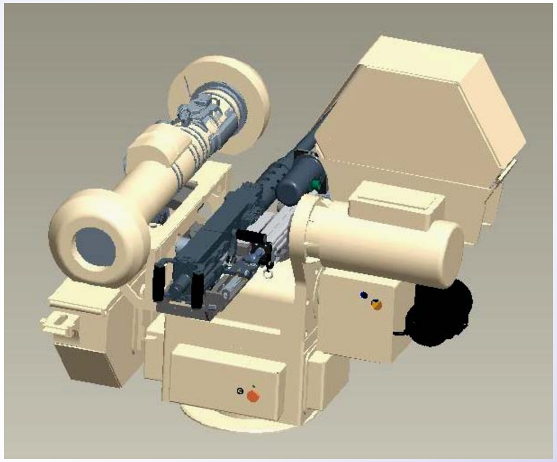
- Integrate a combination ELRF and designator into the current sight package
- Add an azimuth drive system for the sight to improve the stabilization of the sight
  - Verify accurate designation
  - Allow active target leading

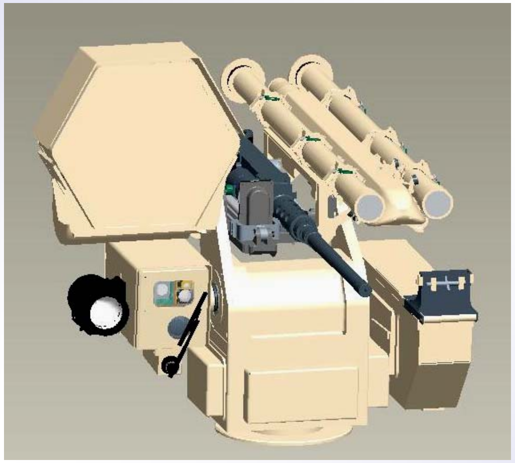


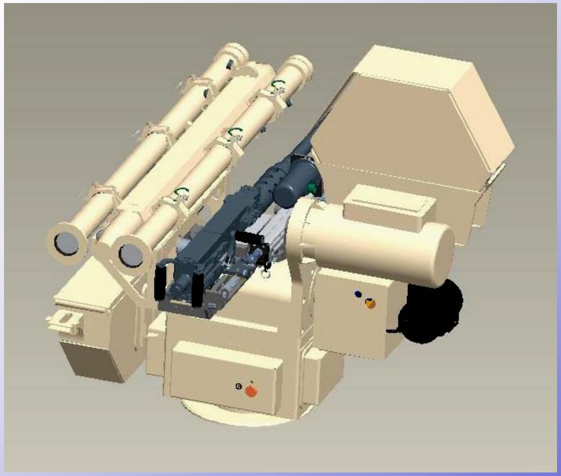
Modular Advanced Weapon System (MAWS)

Missile Options









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Gun and Missile Systems

*An **Integrated** Warfare Perspective*

Mr. Christopher Deegan

Executive Director

PEO Integrated Warfare Systems

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Outline

- Today's Environment
- Where are we going?
- How might we get there?

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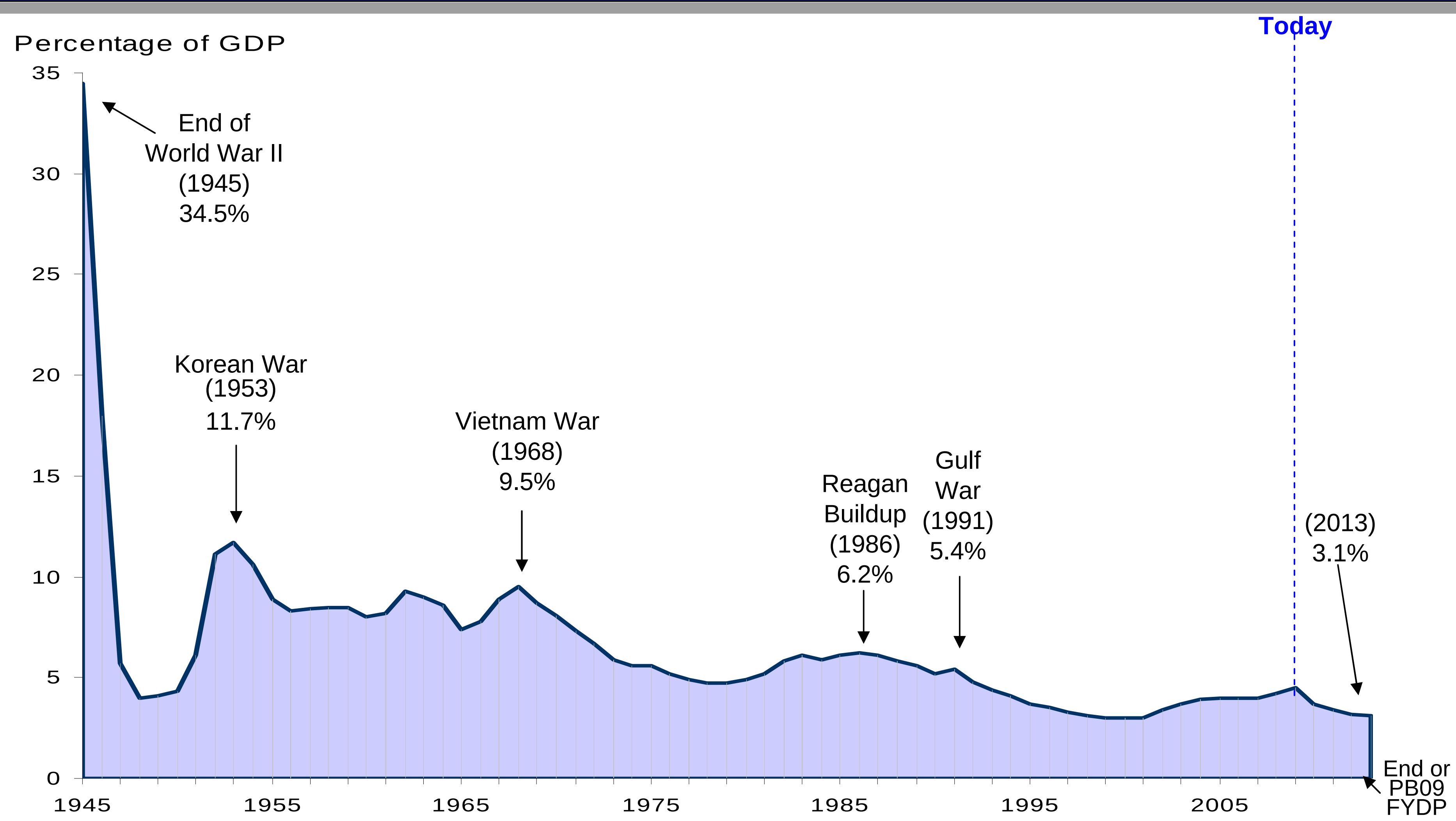
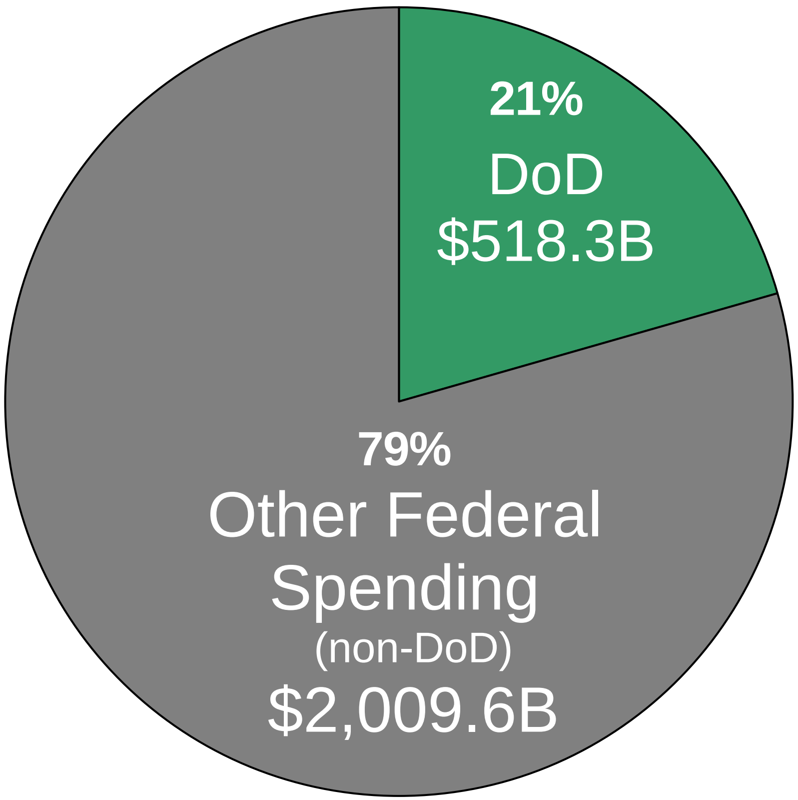
Defense Budget as a Percentage of GDP



Source: Calculations based on Office of Management and Budget, *Historical Tables, Budget of the United States Government, Fiscal Year 2009* (Washington D.C.: U.S. Government Printing Office, 2008), at *www.whitehouse.gov/omb/budget/fy2009/pdf/hist.pdf* (November 27, 2008)

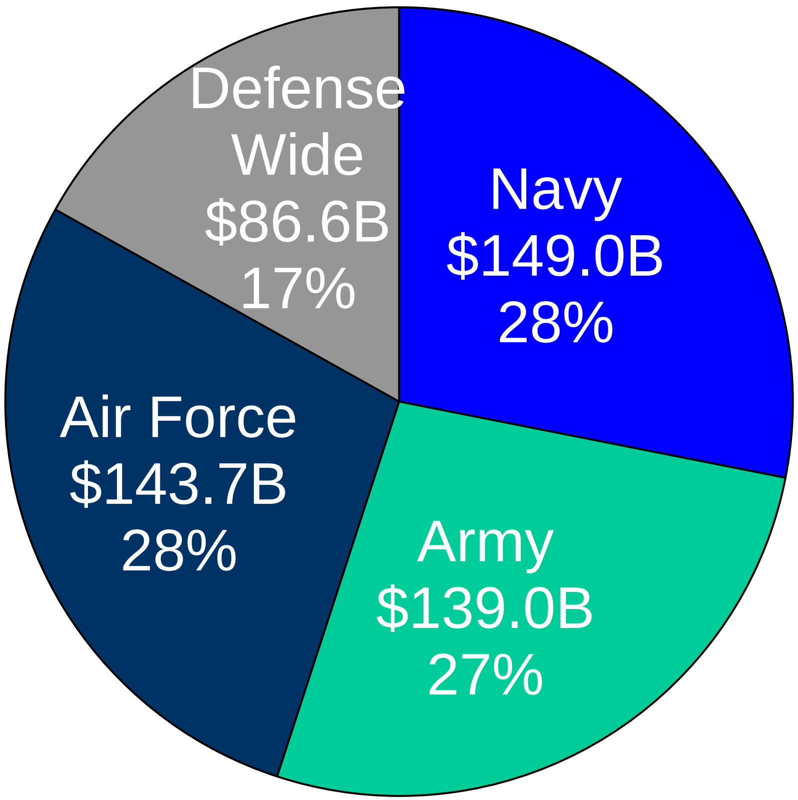
FY2009 Budget Authority

Department of Defense Budget
as % of Federal Budget



Total Federal Budget = $2,527.9B

Department of Navy Budget
as % of DoD Budget



Total DoD Budget = $518.3B
(does not include non-DoD National Defense)

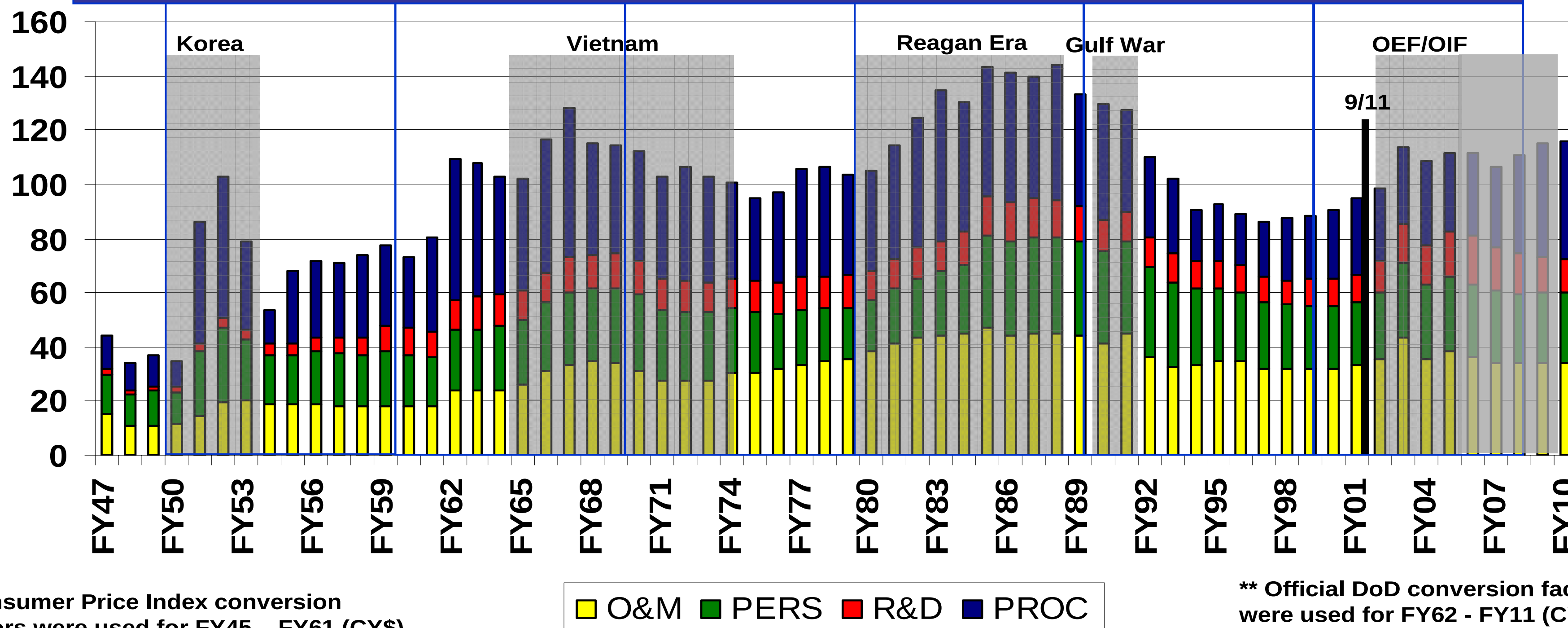
Source: National Defense Budget Estimates for FY2009, September 2008 ("The Green Book")

Navy TOA Profile 1947 - 2010

AVG % of TOA BY DECADE

CY06 $B

	1950s	1960s	1970s	1980s	1990s	2000-2006
O&M	26%	25%	30%	34%	35%	35%
PERS	28%	23%	22%	21%	29%	25%
R&D	7%	11%	11%	10%	10%	13%
PROC	39%	41%	37%	35%	26%	27%

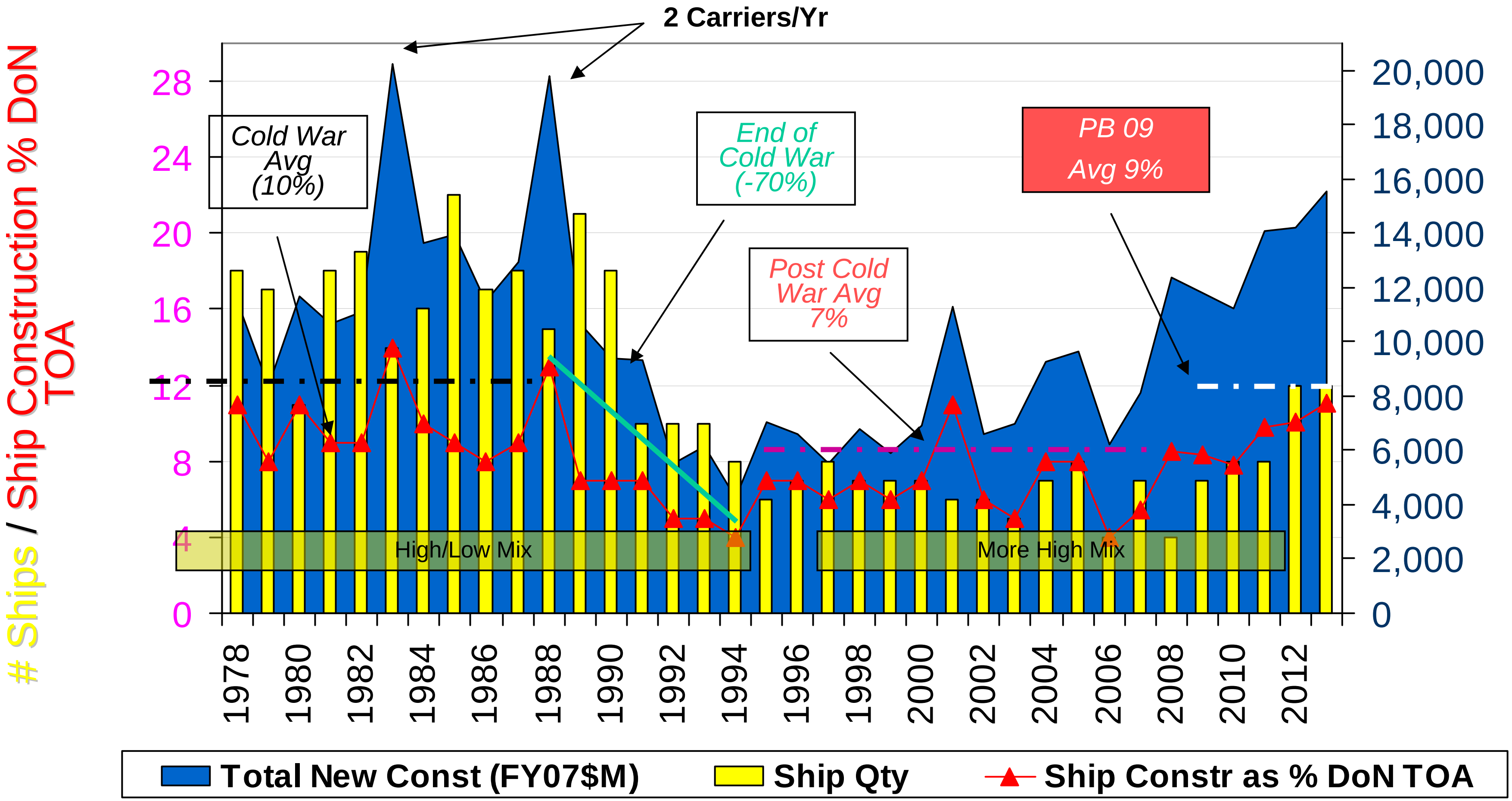


*Consumer Price Index conversion factors were used for FY45 – FY61 (CY$).

** Official DoD conversion factors were used for FY62 - FY11 (CY$).

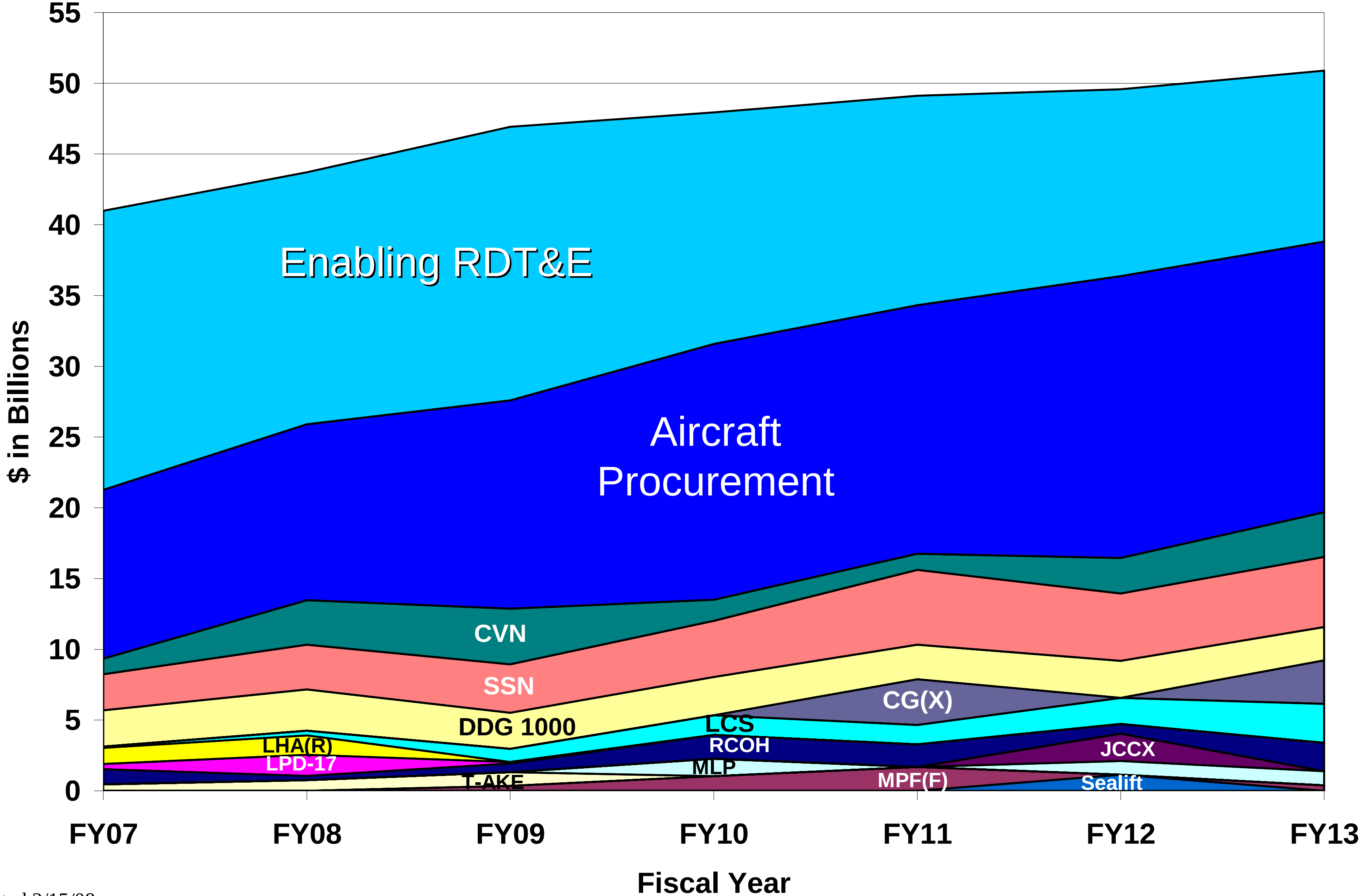
Navy TOA mirrors DoD Underlying Outlay Cycle

Shipbuilding Procurement History
FY2009 President's Budget



FYDP Projections *Now Below* Cold War Averages

Navy R&D and Procurement
FY2009 President's Budget



Updated 2/15/08

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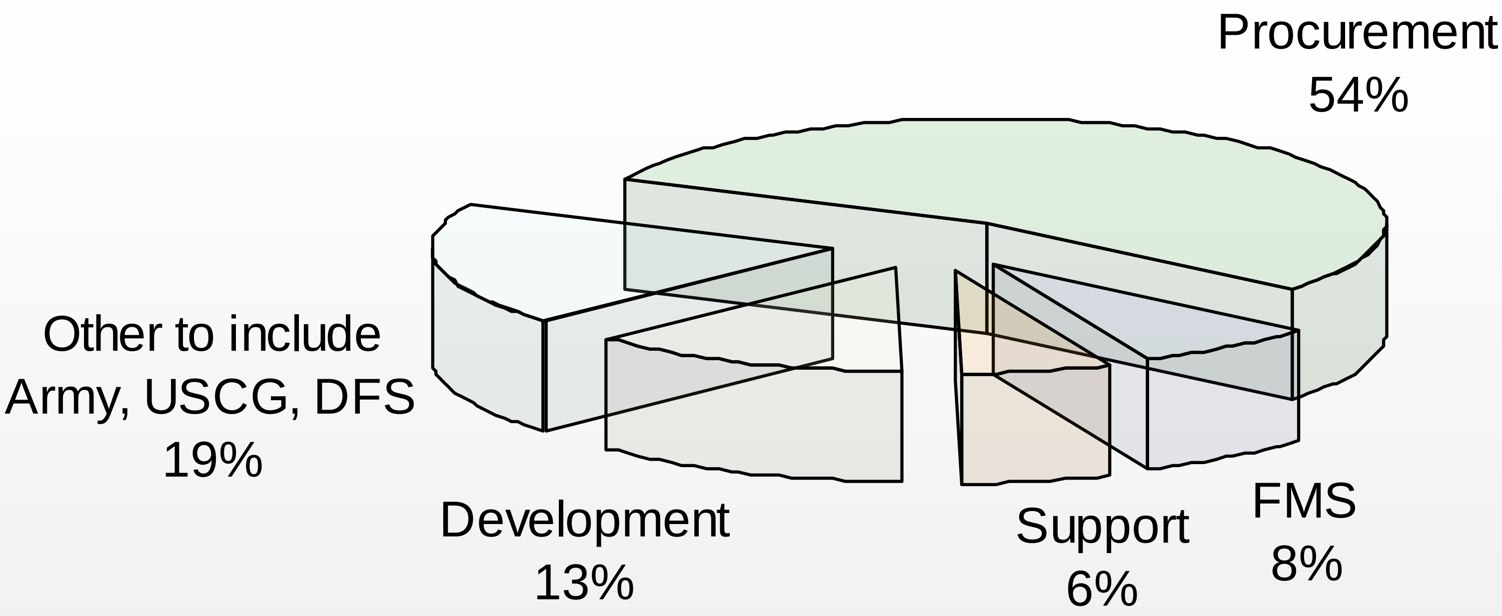
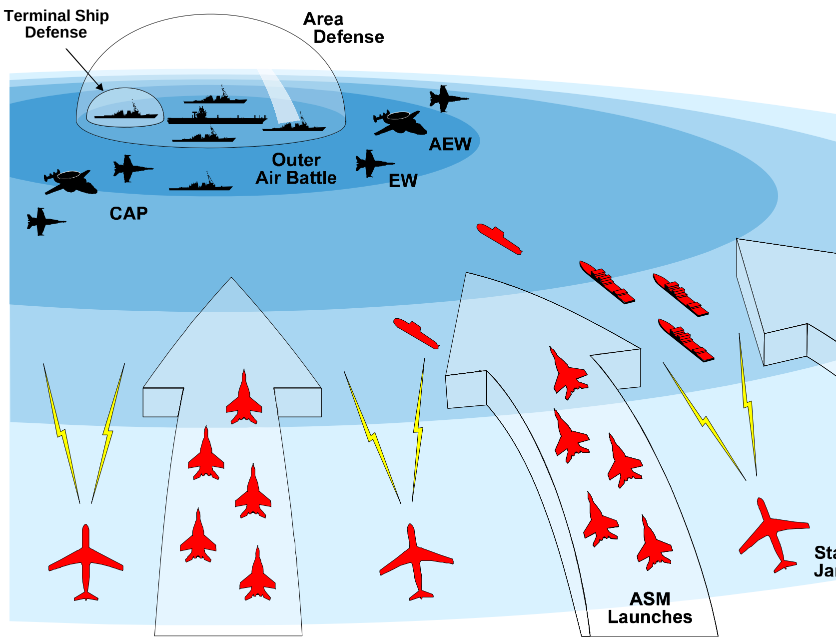
FY09 Weapons Funding Allocations

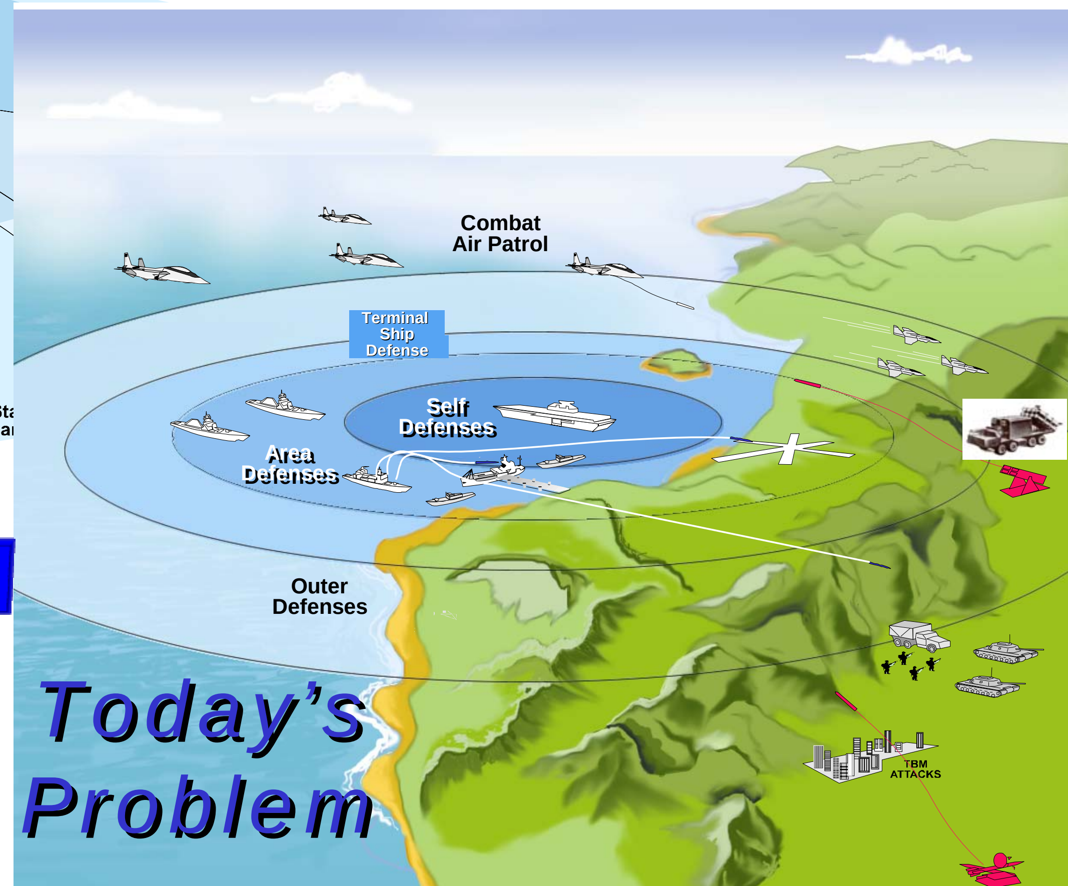


Today - Changing Operational Environment

'Yesterday's' Problem



Blue Water Navy



Littoral/Joint

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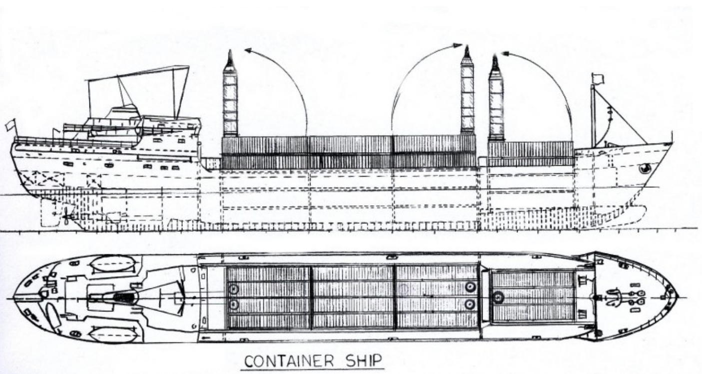
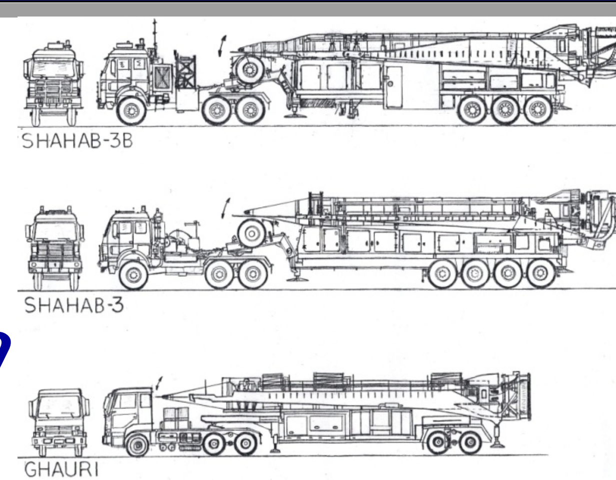
New Threats
…and Some Old Ones



DHS/MDA concerns to hide ballistic Missile

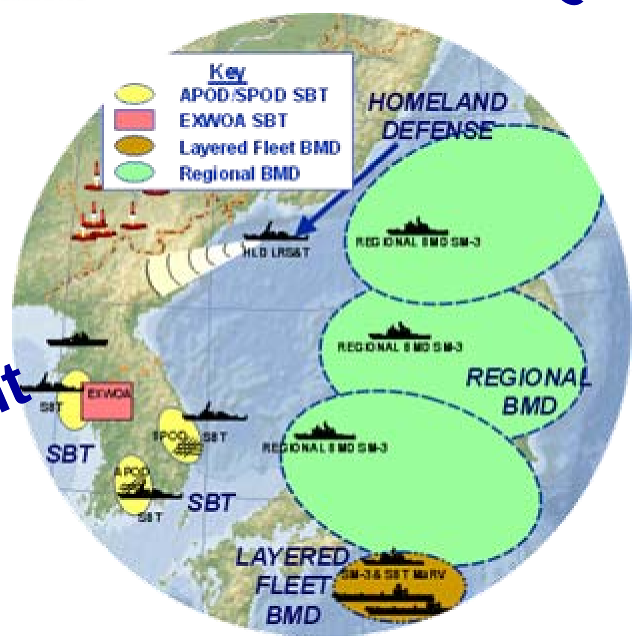
China tests Russian submarine missile



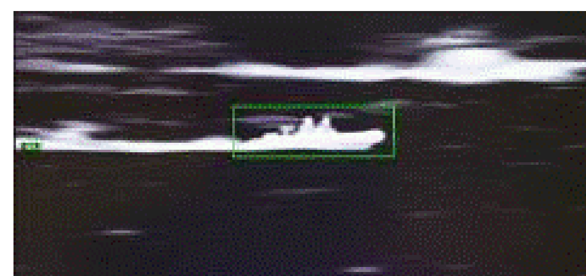
Mobile Missile Launcher

NO-DONG - A DESIGN HERITAGE

Russia offers Yakhont missile for export



US protests Iran Harassment of US ships



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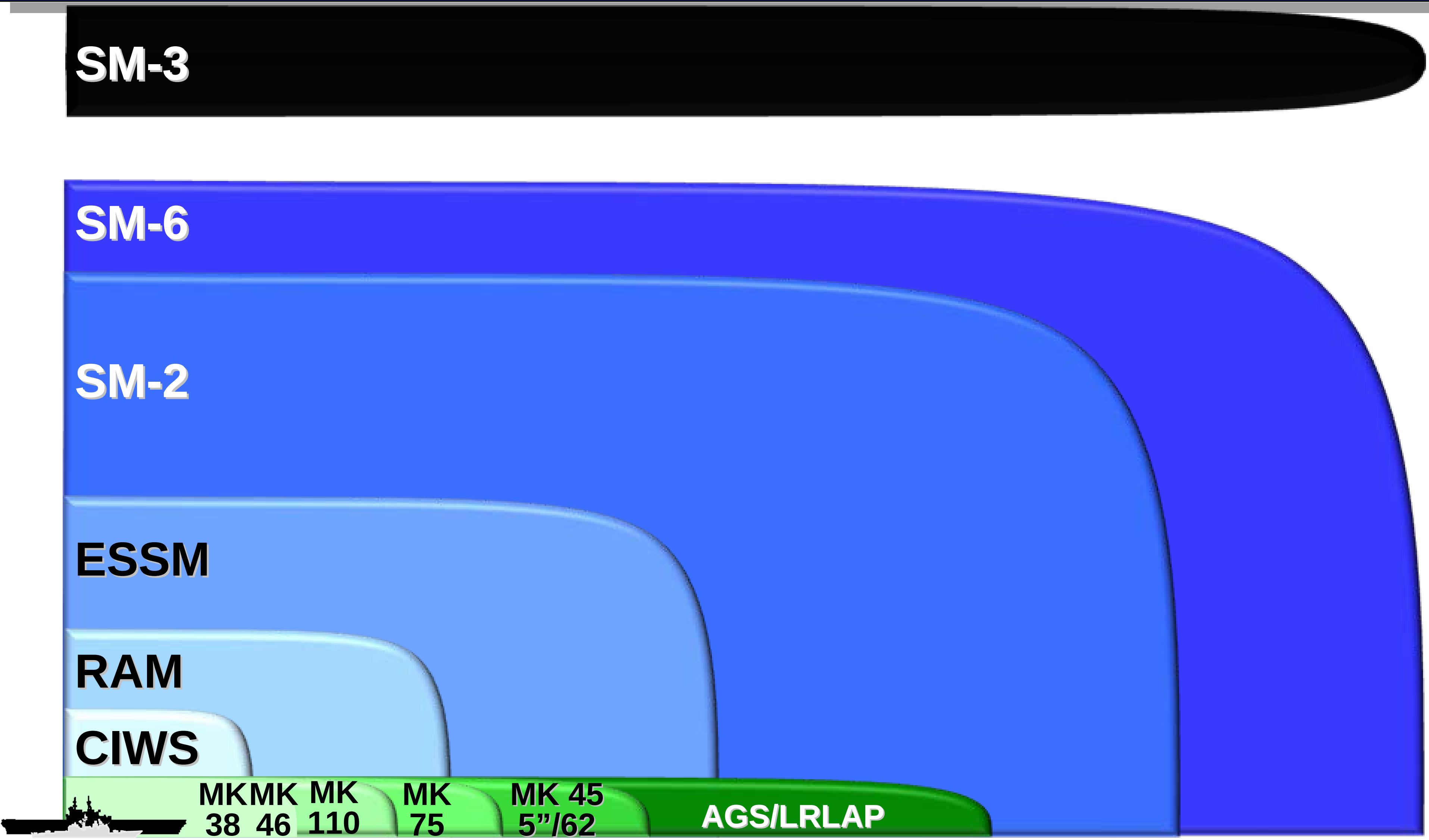
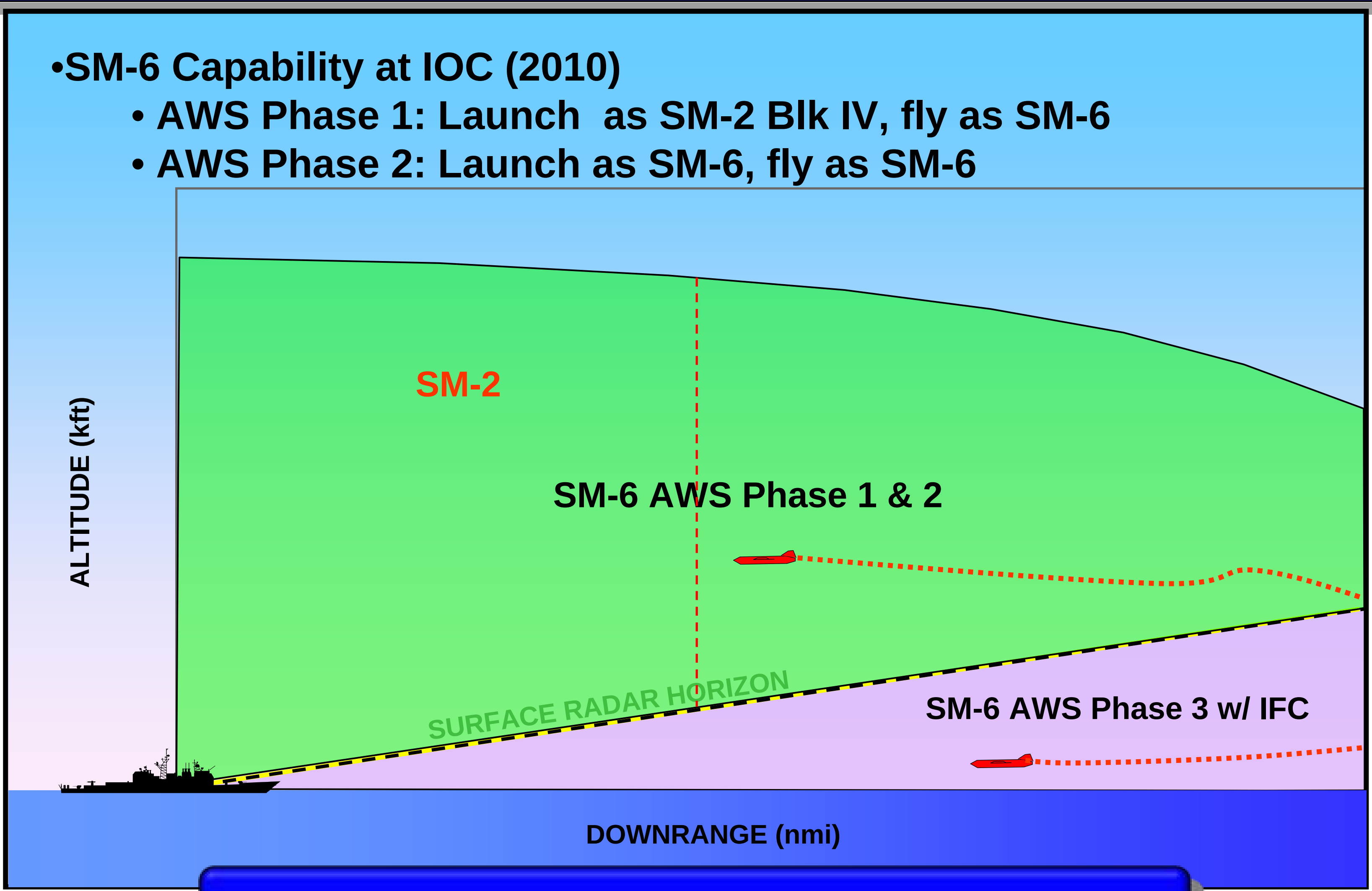
Diversity in the threat.... Results in an uneasy peace...

Surface Ship Weapons Defense in Depth



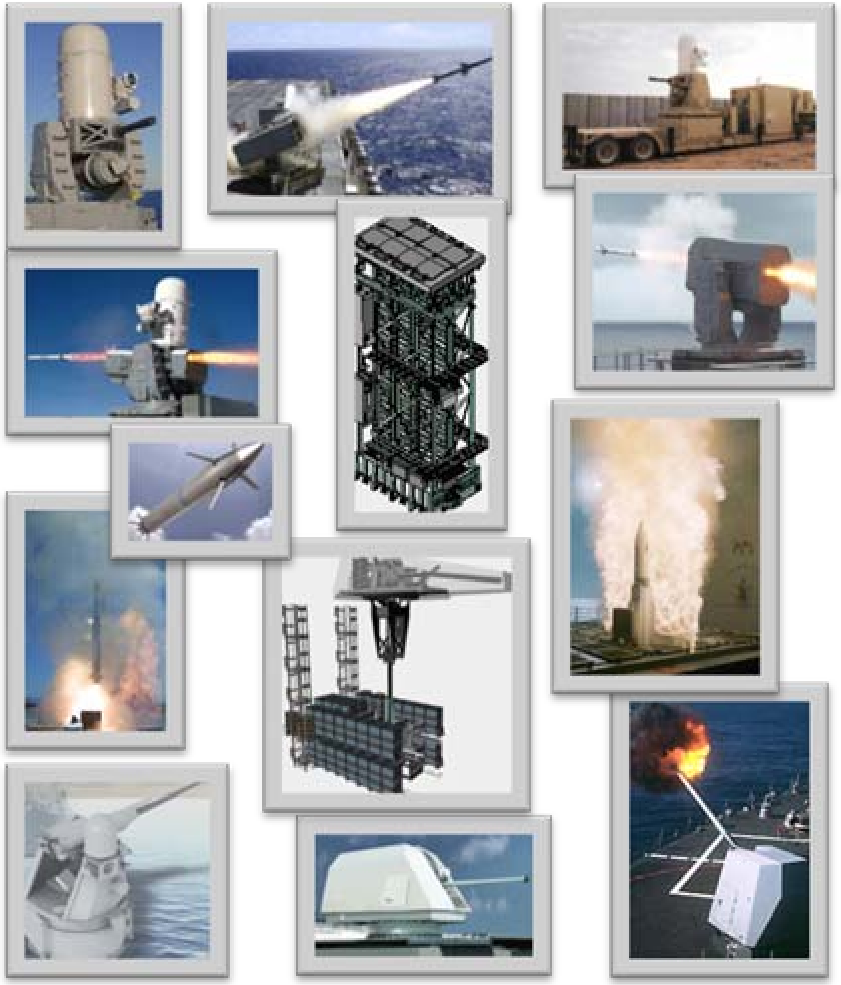
SM-6 Battlespace



SM-6 Buys Battlespace ….. Game Changer

PEO IWS
Supporting the Warfighter Today

Mission
- Force Protection
- Counter-Rocket Artillery & Mortar (Phalanx)
- Anti-ship cruise missile defense
- Fleet area air and missile defense
- Joint theater air and missile defense
- Anti-Surface Warfare
- Naval Surface Fire Support



Description
- Autonomous and/or integrated close-in weapons
- Lightweight, low cost, high firepower ASMD
- Medium range, all-weather, guided missiles
- Extended range surface-to-air missile
  - Compatible with joint integrated fire control
- Advanced Gun System / 155mm LRLAP
- Digital, joint-integrated, naval fires control system
- Conventional naval gun systems and ammunition
  - Major, intermediate, minor caliber, and small arms

Platforms
- Land-based C-RAM for US and allied ground forces
- CVN, LHD, LHA, LSD, LPD, CG, DDG, FFG, LCS
- Fifteen allied navies

Employment
- Effective against current and future air threats
- Layered defense against terrorist and conventional small fast surface craft
- Engage land targets at long range with precise, high volume fires

PEO IWS
Guns and Gun Weapon Systems

Medium / Minor Caliber Gun Weapons System Mission:

- Warning, disabling & destructive gun fire to respond anti-small boat asymmetric threats in support of Surface Warfare (SuW) and low, slow flyers.

Description:
- Minor Caliber Guns: Lightweight, low cost, remotely controlled stabilized gun weapon systems with on-mount Electro-Optic Fire Control System (EOFCS)
- Medium Caliber Guns: Main battery deck guns on frigate size platforms; also used as secondary battery on DDG 1000 Destroyers.

Ships:
- DDG / CG
- LPD-17 / LPD / LHD
- Large Deck Amphibs
- FFG Class Frigates
- Littoral Combat Ships (LCS)
- US Coast Guard Cutters
  - WMSL / WHEC / WMSM / WMEC / WPB

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Surface Ship Weapons Missiles

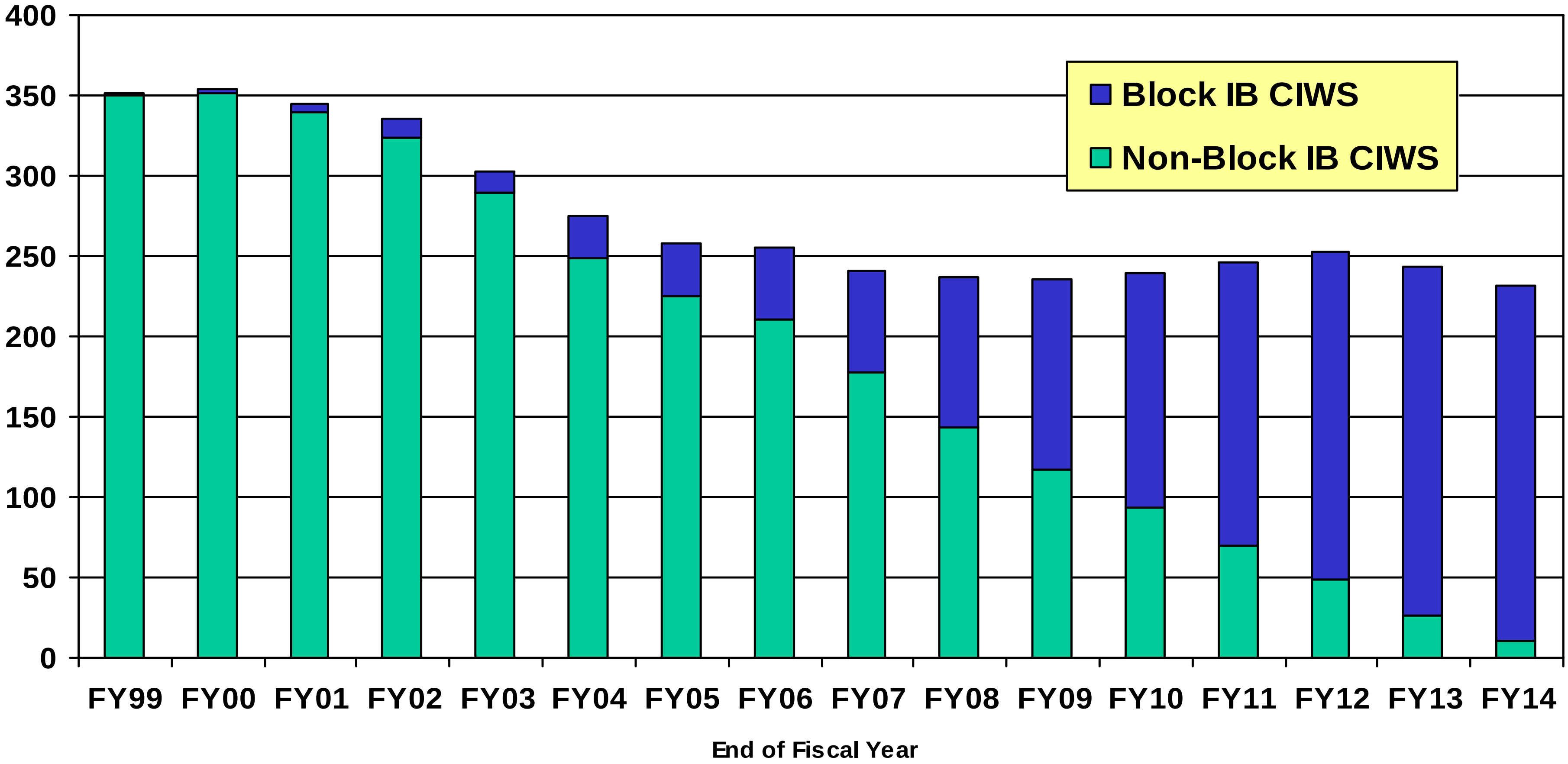
Present: Tomahawk, SM-2, 73 Ships · SM-3, 18 Ships · ESSM, 24 Ships · RAM, 38 Ships

FY 2015: Tomahawk, SM-2, 86 Ships · SM-3, XX Ships · SM-6, 84 Ships · ESSM, 98 Ships · RAM, 75 Ships

Ship	Present	FY 2015	
DDG 51-78 * 28 Ships	SM-2	SM-2 + SM-6 + ESSM	28 Ships
DDG 79-112 23 Ships	SM-2 + ESSM	SM-2 + SM-6 + ESSM	34 Ships
CG 52-73 * 22 Ships	SM-2	SM-2 + SM-6 + ESSM	22 Ships
DDG 1000 In Design		SM-2 + ESSM	2 Ships
CV/CVN 12 Ships	RIM-7 + ESSM + RAM (11 Ships, 1 Ship)	ESSM + RAM	11 Ships
LHA 6 In Design		ESSM + RAM	1 Ship
LHD 7-8*	RIM-7 + RAM	ESSM + RAM	2 Ships
LHD 1-6 8 Ships	RIM-7 + RAM	RAM	5 Ships
LHA 1 3 Ships	RAM	RAM	2 Ships
LSD 41 12 Ships	RAM	RAM	12 Ships
LPD 17 4 Ships	RAM	RAM	9 Ships
LCS 2 Ships	RAM / SeaRAM	RAM / SeaRAM	33 Ships

* Some are ABMD / SM-3 capable

CIWS Population
(Block IB vs. Non- Block IB)



Increasing capability without increasing footprint.

Note: Includes past and projected decommissioning of Fleet Units.

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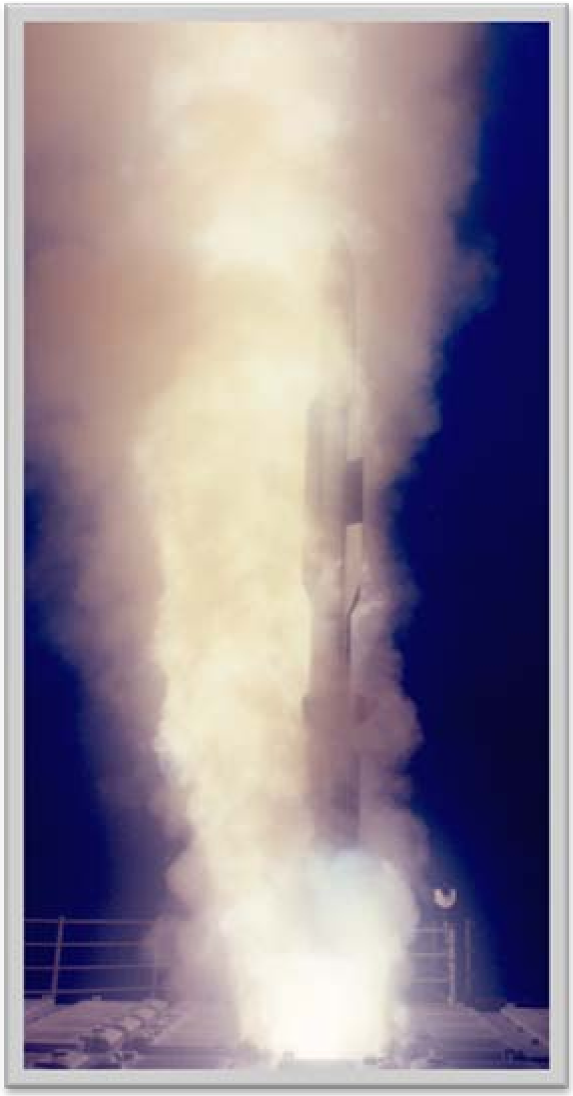
Future Direction

- **Expand the Battlespace to Defeat Evolving Threat**
- **Improve Systems and Employment**
- **Support the Warfighters' Requirements**

Quality....
Let's not forget about it!



PEO IWS Future Direction

ASW Development
- SQQ-89A(V)15 SIPS
- ARCI / APB
- Periscope Detection Radar
- SSDT
- Distributed Netted Sensors
- ASW Combat C^2
- LCS ASW MM
- Twin-Line TB29
- **Task Force ASW/ Transformational Technologies**

Gun Development
- AGS, CIWS 1B+, Medium & Minor Caliber Guns

Missile Development
- SM-3, SM-6, RAM Blk 2, ICWI, P^3I Link, Adv. Int. Range Missile

Radar Development
- *New Development*
  - SPY-3, S-VSR → DBR
  - CJR S, CJR X → CJR Suite
  - Low-Cost Radar, Periscope Detection → SPS-49 / SPN-43 Replacement
- *Radars for new ships*
  - DDG 1000
  - CVN 78
  - CG(X)
- *Future Radar Suite*

OA CS Applications
- DDG 1000 Functionality
- IABM / SIAP BMD Merge
- SBT NIFC-CA

OA Computing Environment
- Aegis BL 7.1 HW Architecture
- SSDS Mk 2 HW Architecture
- DDG 1000 TSCE
- Future Open, Modular, Scalable, Multi-level, Computing Environment for Future Platforms

Enterprise Processes
- Common Cert
- Enterprise T&E
- Common Displays
- Next Generation ISE
- Ship Construction Innovation
  - Warfare System Turnkey
  - Standardized Ship Hotel Spaces
  - Multiyear Ship Procurement

- Common enterprise solutions
- Effective warfighting capabilities
- Create culture of aligned warfare system acquisition & life cycle support

Navy Enterprise Warfare Systems

Transition from Platform to Enterprise Solutions

PEO IWS Missile and Gun Evolution

Guns	Today	2014	TBD
Major Caliber	• MK 45 5"/54 • MK 45 5"/62	• AGS • MK 45 5"/54 • MK 45 5"/62	• AGS • TBD
Intermediate Caliber	• MK 110 57mm • MK 75 76mm	• MK 110 57mm • MK 75 Mod 0	• TBD
Minor Caliber	• MK 46 30mm • MK 38 25mm	• MK 46 30mm • MK 38 25mm	• MK 46 30mm • MK 38 30mm

Missiles	Today	2014	TBD
Long Range Area Defense	• SM-2 Blk IV	• SM-6	• SM-6
Medium Range Area Defense	• SM-2 Blk III • SM-2 Blk IIIA • SM-2 Blk IIIB	• SM-2	• Advanced Intermediate Range Missile
Short Range Self Defense	• RIM-7P (NSSM) • ESSM	• ESSM	
Terminal Defense	• RAM Blk 0 • RAM Blk 1A • CIWS Blk 1B • SeaRAM	• RAM • CIWS Blk 1B • SeaRAM	• RAM • SeaRAM

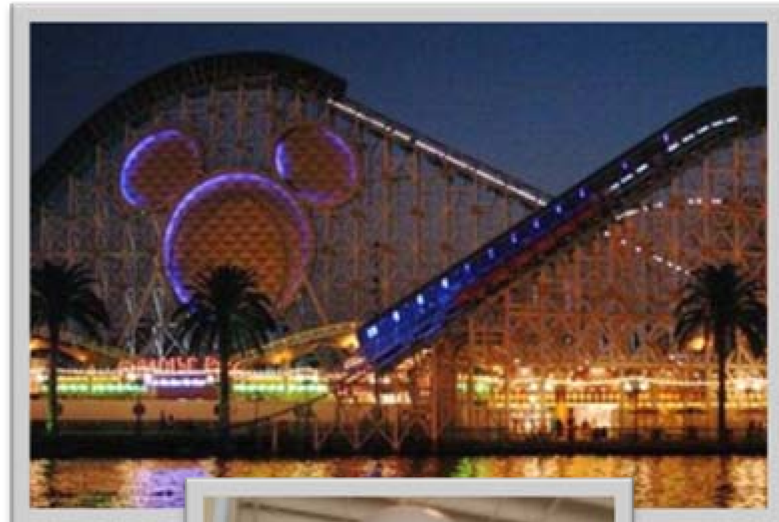
Advanced Intermediate Range Missile

- **Fill anticipated Gaps between SM-6 ER Active and RAM Block II**
  – Each will IOC in 2011
- **Dual Mode Semi-Active and Active Seeker**
- **SM-2 Block IIIB and ESSM were introduced in Mid 1990s.**
- **Investment to Pace the Threat**
    - Develop Capability to Defeat Future Air Threats at Intermediate Ranges

UNCLASSIFIED

Future Trends
Fighting at Hypervelocity

- **Current Surface Ship Weapons programs have planned product improvements through the mid term, i.e. 2015.**
- **Hypervelocity and Directed Energy Technologies are the future of Surface Ship Weapons and Launching Systems**
- **Enablers:**
  - New and improved power systems on future ships
  - Advanced materials and manufacturing techniques
- **Electromagnetic Rail Gun**
- **Free Electron Laser**
- **Solid State Lasers**
- **High Power Microwaves**
- **Enhanced Weapon System Technologies**



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Summary

- **Persistent Technology Innovation is the US Asymmetric Advantage**
  - Problem never gets any easier
- **Government/Industry Partnership will get Us to the Next Generation of Capability**
- **Integrated Guns and Weapon system Approach Ensures Maximum Benefit from Our Efforts**

Demilitarization

Design for Demil Efforts at GD-OTS




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Demil Program Manager
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GENERAL DYNAMICS
Ordnance and Tactical Systems

GD-OTS Large Caliber Ammunition Product Portfolio

120mm Tank Ammunition

Guided Projectiles

Mortar Weapons

105mm and 155mm Artillery

Coalition Supply and Support Services (CS3)

Expeditionary Fire Support System

Pipe Joints

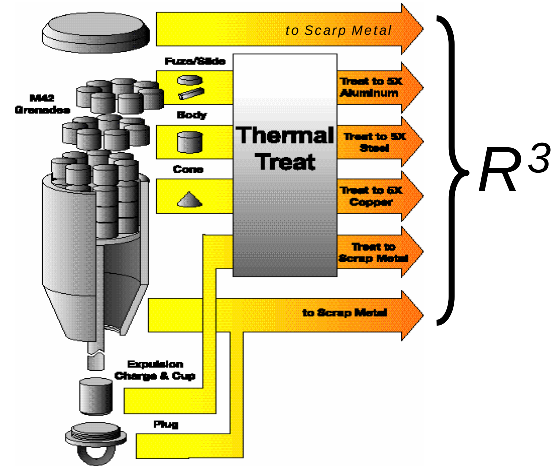
Demil

GENERAL DYNAMICS
Ordnance and Tactical Systems

RRR DEMIL

GD-OTS – Commercial Demil Prime Contactor

- General Dynamics (GD) has been involved in Demil work since mid 1980s
- Since 1999 GD Ordnance and Technical Systems (GD-OTS) is a Systems Contractor for the US Army
  - 5 year program with 43,000 ton ammunition disposal
  - Approximately 600 tons per month processed at various facilities
- Since 2005 GD-OTS is a Demil Sole Source Systems Contractor to US Army
  - Currently 4 years, 106,000 tons ammunition
  - 2,350 tons per month average
  - 4,550 tons – highest month to-date



GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

WHY DEMIL?

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

Life Cycle Need for Demilitarization

- **Weapon Platforms and ammunition have a life-cycle, become obsolete, and end up in the Demil Stock Pile**
- **Demil stocks decay and create hazards, environmental, and security problems**
- **Disposal cost continue to increase with changes in environmental regulations**
- **Demil is the only storage solution that creates space in the depots**


Corroded Projectiles


Corroded Cartridges


Corroded Projectile

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

Practical Reasons for Demilitarization

- Demil stocks impede the depots' wartime support mission
- Tax Payers are spending lots of money to secure, maintain and inventory obsolete ammunition
- Obsolete Ammunition is occupying covered storage space at key ammunition out load depots
- Demil stocks occupy space inefficiently
- Stability of propellant and energetics a long-term safety hazard

Store, Secure, Maintain and Inventory obsolete Ammunition is a Waste of Money and Resources

Impacts to Demilitarization

- Political pressure can restrict or eliminate use of many ammunition items
  - Cluster Ammunition
  - Depleted Uranium
  - "Dumb" Ammunition
  - Suspected Carcinogens
- Environmental impact
  - Sea dumping
  - Open Burn
  - Open Detonation
  - Land Filling

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

DEMIL REQUIREMENTS

Demil Environmental Requirements

- Open Burn / Open Detonation is not an option – only available to USG Depots and becoming obsolete
- Must meet all local, state, and federal environmental regulations

➔ adds cost to demil process

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

Demil Requirements

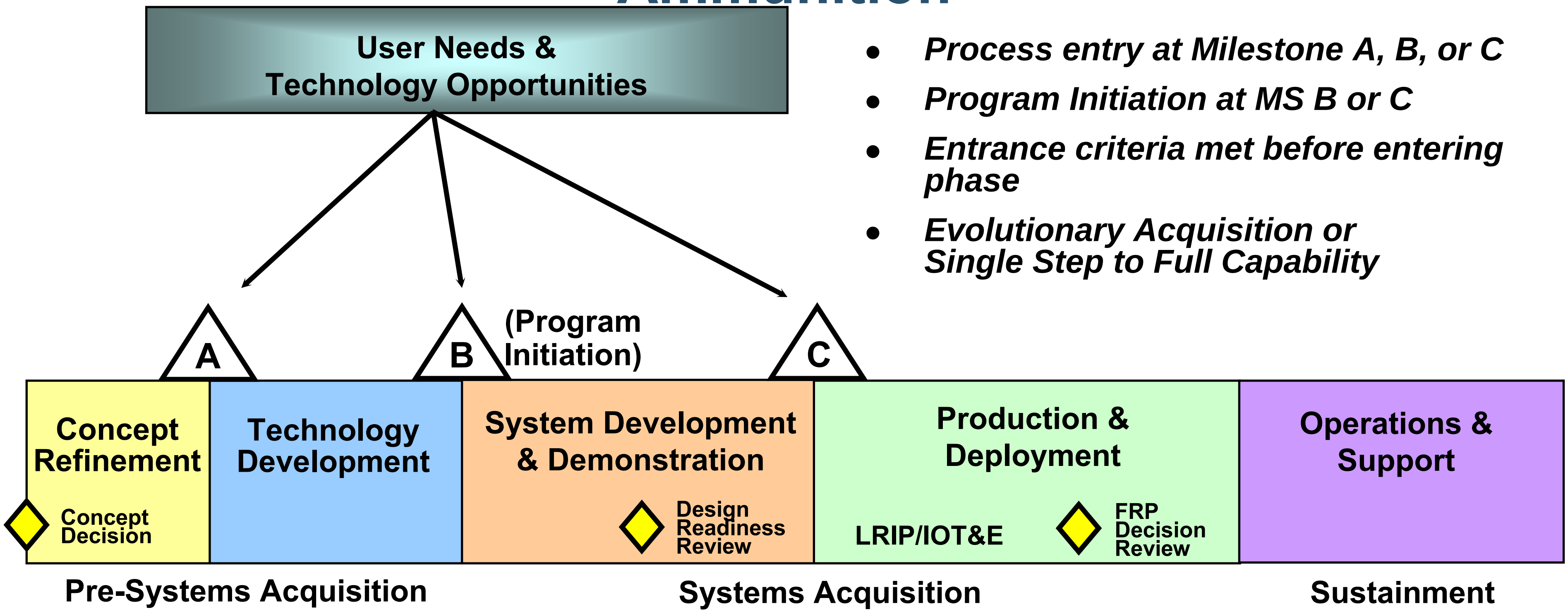
- Many demil processes require state-of-the-art technologies to deal with ammunition designs from 25-50 years ago

➔ adds cost to demil process

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

Typical Program Life Cycle for Conventional Ammunition



- *Process entry at Milestone A, B, or C*
- *Program Initiation at MS B or C*
- *Entrance criteria met before entering phase*
- *Evolutionary Acquisition or Single Step to Full Capability*

Historically, Demil has not been considered part of the Life Cycle

GENERAL DYNAMICS
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DEMIL

Design for Demil

- ➢ Demil needs to part of the systems engineering throughout the ammunition design and production phases to reduce overall life cycle cost

Design for Demil Challenges:

- ➢ Design is driven by performance, cost, and schedule
    - Demil adds additional constraints to each
- ➢ Actual Demil does not occur for 10+ years after development and production
- ➢ Design for Demil requirement must be measureable and verifiable

Requirements for Design for Demil

- Demil design requirements shall be defined in acquisition documentation
- Demil design requirements shall be included in the systems engineering process and documented in the Systems Engineering Plan
- Design for Demil activities and status shall be addressed in all program reviews
  - IPT meetings
  - Preliminary and Critical Design Reviews
  - Milestone entrance / exit reviews
- Valid and realistic demil cost estimates
- Demil Plan developed prior to milestone C
- Demil testing conducted during Developmental Testing

GENERAL DYNAMICS
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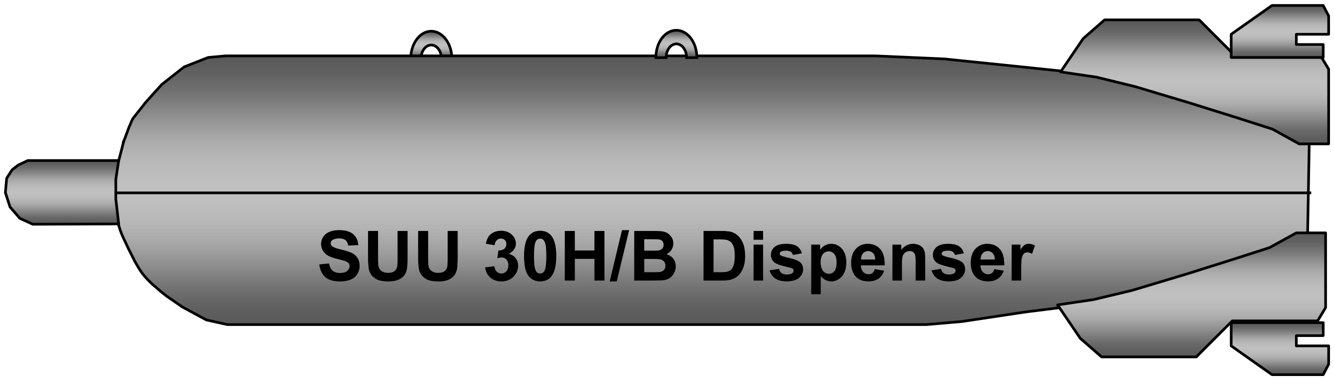
DEMIL

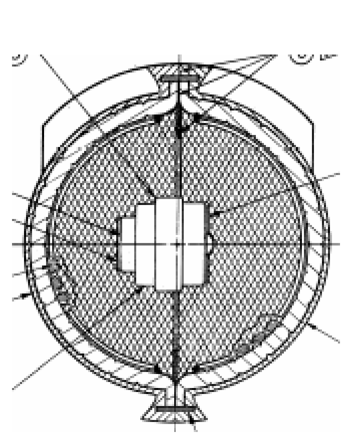
POOR DESIGN ⟶ INTRICATE DEMIL

GENERAL DYNAMICS
Ordnance and Tactical Systems

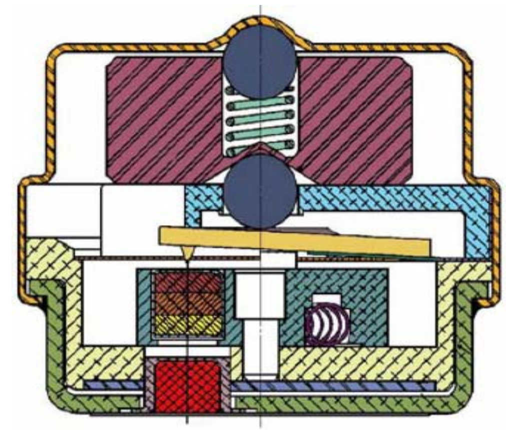
Cluster Bomb Demil Facility at EBV EEC



CBU Bomblets



Bomblet Cutaway View



Spin Arm Fuze

GENERAL DYNAMICS
Ordnance and Tactical Systems

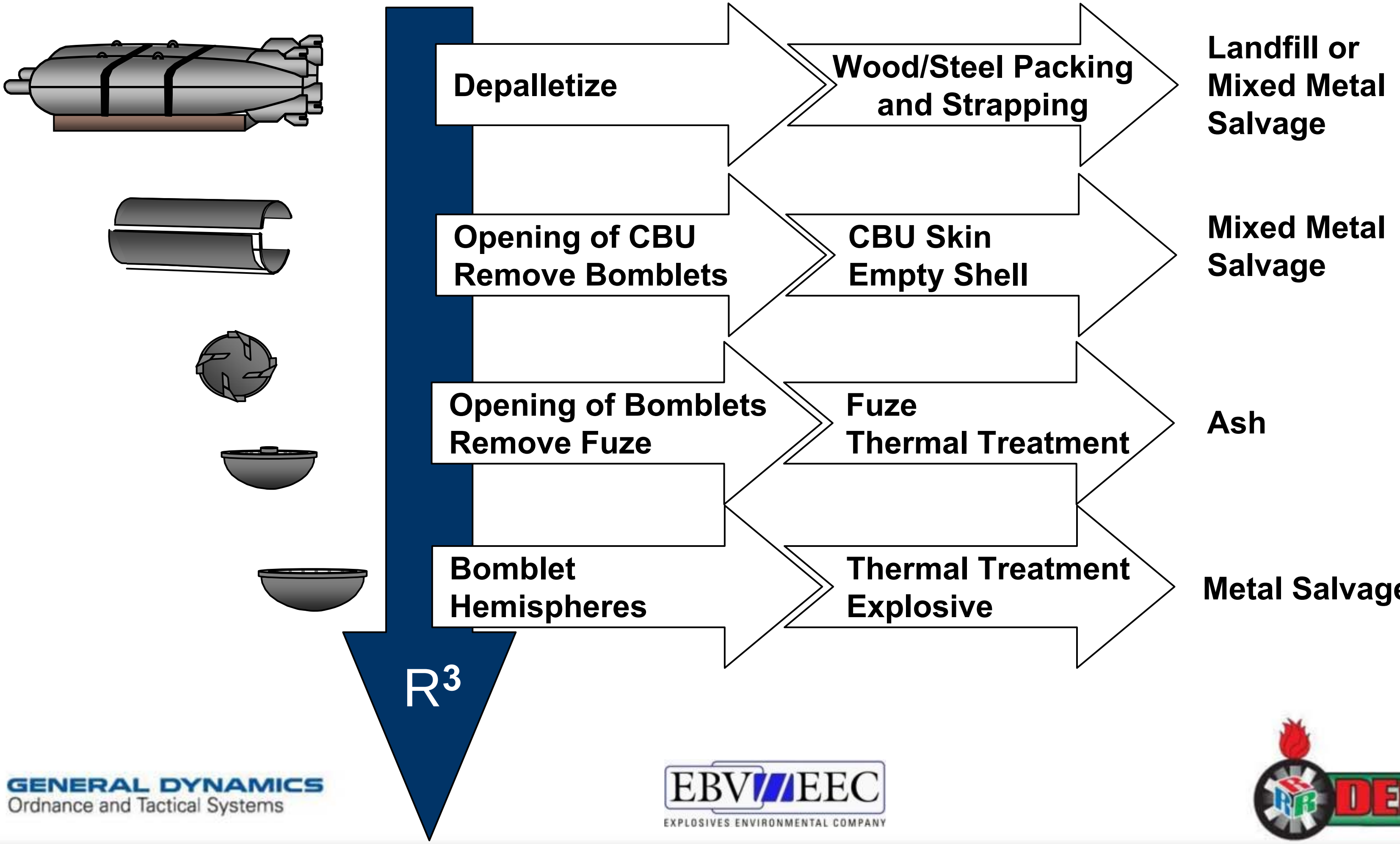
EBV EEC
EXPLOSIVES ENVIRONMENTAL COMPANY

DEMIL

Cluster Bomb Facility Requirements

- **Combination of Automated and Manual Operations**
  - **Maximum Safety / Minimum Risk**
  - **To Achieve Highest Process Efficiency**
- **High Volume Throughput**
  - **To Complete Contract Requirements**
  - **Enough Capacity to Deplete similar assets in Demil Inventory**
- **Low Maintenance Requirements**
- **Bomblet Disassembly Operations are Remote Controlled with Video Monitoring**
- **Thermal Treatment of Energetics**
- **Robust process for Asset Variation**

General Processes Cluster Bomb Family



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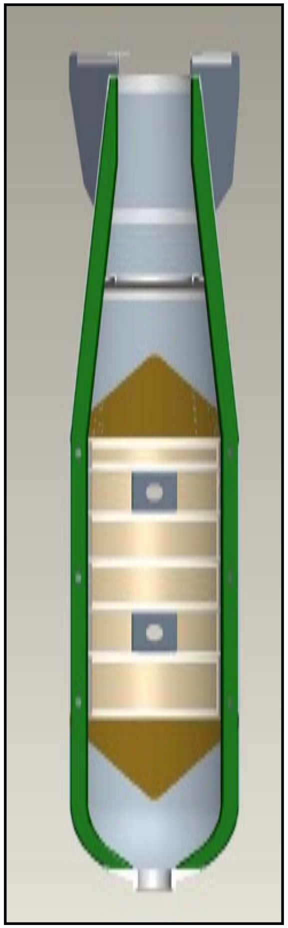
EXPLOSIVES ENVIRONMENTAL COMPANY

DEMIL

Production Methods - CBU Loading of Bomblets



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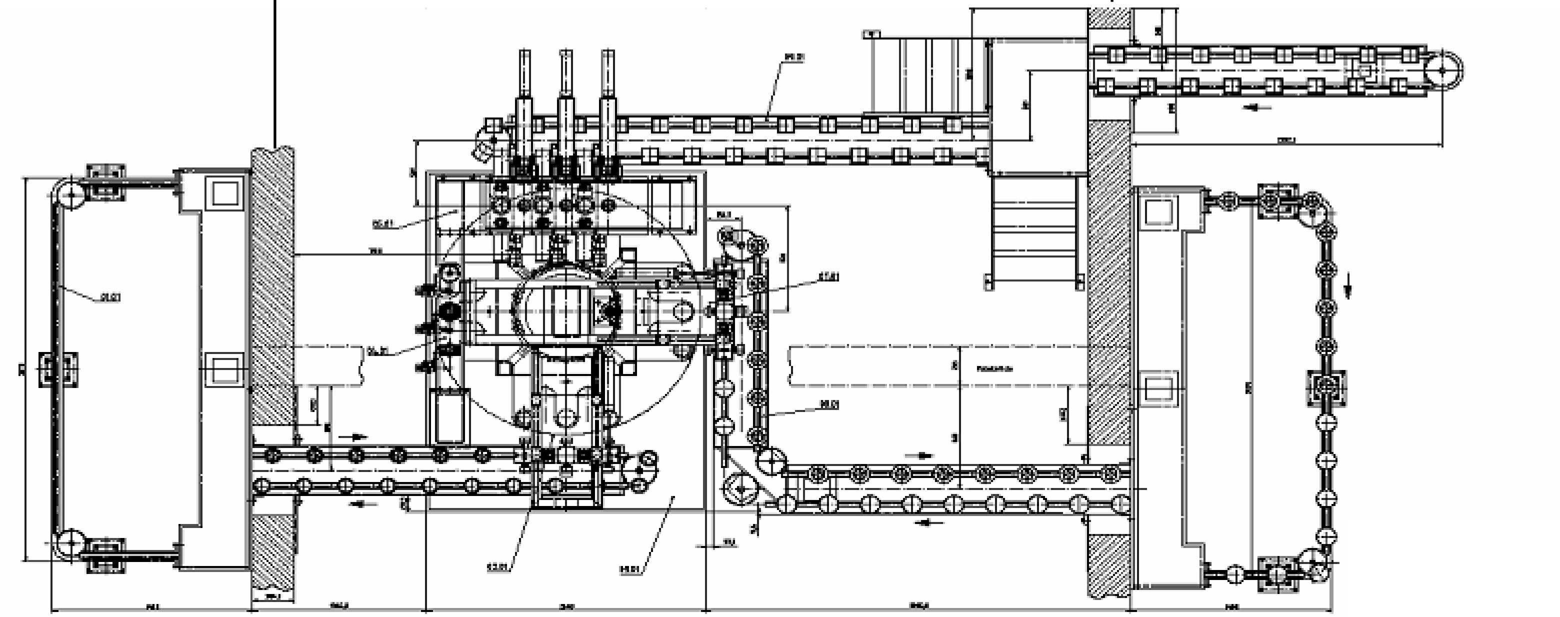
DEMIL

CBU Disassembly Line – Overall Layout

Input Bay | Safety Cell / Disassembly Bay | Output Bay



Top View

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CBU Demil Line – Processing Equipment

Disassembly Machine in Safety Cell

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DEMIL

Current CBU Demil Line Facilitization

R^3

GENERAL DYNAMICS
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EBV EEC
EXPLOSIVES ENVIRONMENTAL COMPANY

DEMIL

Demil Center of Excellence for Cluster Ammunition

- GD-OTS has teamed with EBV EEC to Create the Leading Center of Excellence for Demil of Assets Containing Submunitions
- Engineered Solutions that are Safe, Robust, Efficient, and Low-Cost
- Proven Capabilities across Range of Demil Items
- Design and Implementation of CBU Line in 8 months
- Generation 4 ICM Line in Operation

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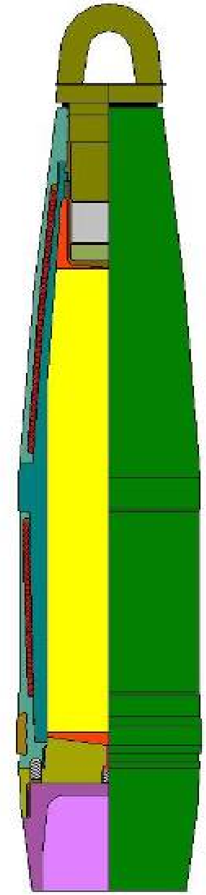
EXPLOSIVES ENVIRONMENTAL COMPANY

DEMIL

GOOD DESIGN → SIMPLE DEMIL

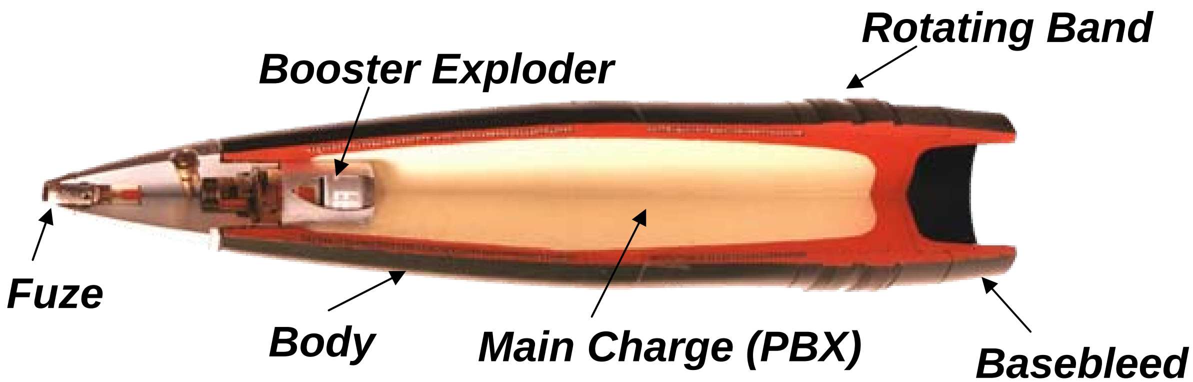
M1130 105mm PFF Background



- In 2002, the Advanced Cannon Artillery Ammunition Program (ACA2P) was created to help modernize conventional artillery ammo
- Need for high effectiveness against soft targets without the use of DPICM's
- Recently Type Classified
- IM requirements aided design being demil friendly

GENERAL DYNAMICS
Ordnance and Tactical Systems

Demil Processes - M1130 105mm IM HE PFF



Main Demil Processes:

- Basebleed – Unscrew and thermally treat
- HE Explosive Fill
  - Simple access by extracting pins and unscrew plug
  - Waterjet washout of HE and recycling
- Flash projectile body to react booster
- Thermally treat fuze
- >97% Resource Recovery and Recycle (R^3) Rate

Simple and low cost Demil solution

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

GD-OTS Design for Demil Summary

GD-OTS uniquely positioned for Design for Demil activities:

- In-house ammunition development and production expertise
- In-house demilitarization expertise
- Entire life cycle management

GD-OTS Design for Demil Services:

- Design for Demil Requirements Analysis
- Demilitarization Systems Engineering
- Demilitarization Plan Development
- Demil Cost Estimations
- Design for Demil Activity Management

GENERAL DYNAMICS
Ordnance and Tactical Systems

DEMIL

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Copper Cone Recycling

Bombs to Wheels

GENERAL DYNAMICS
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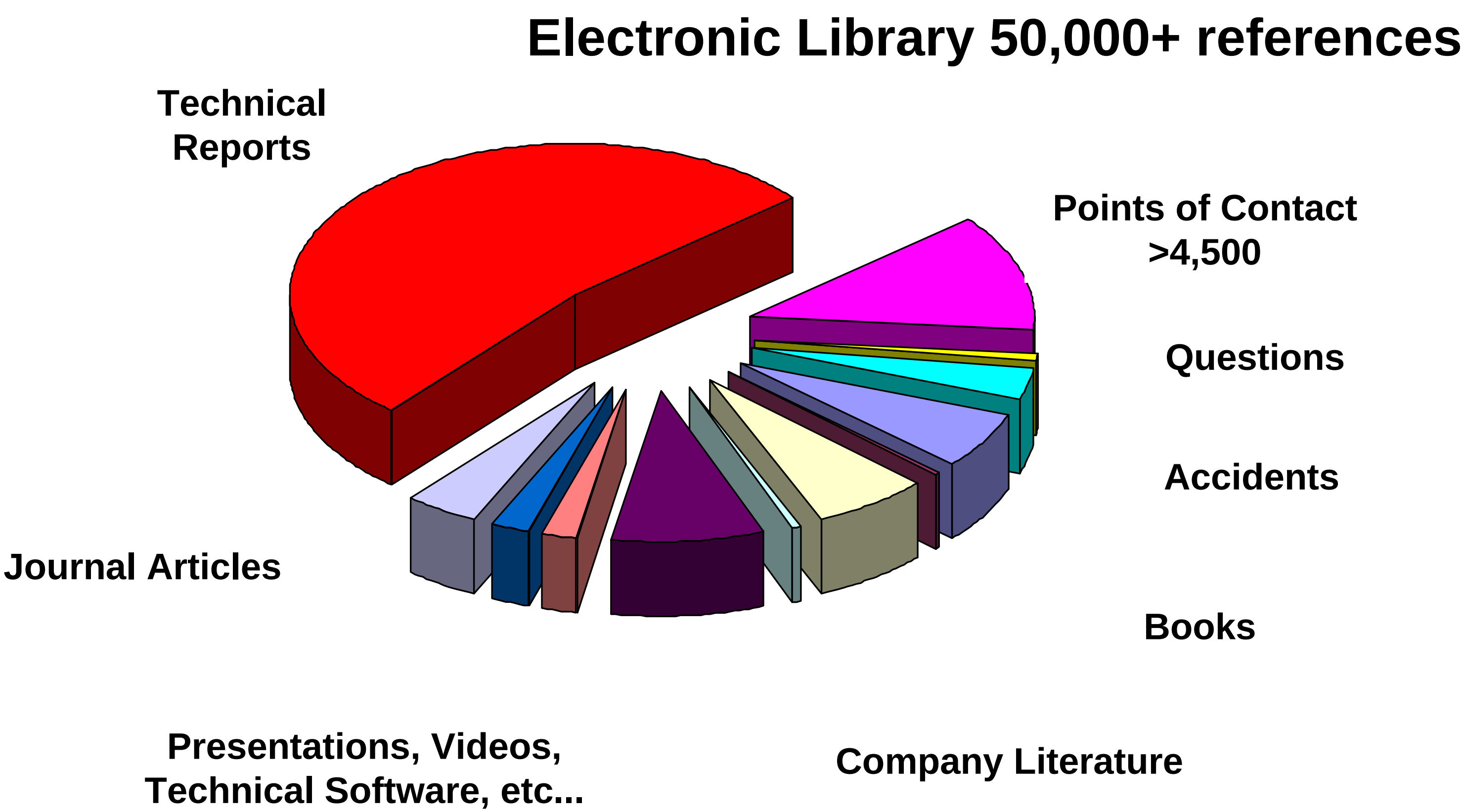
DEMIL

MSIAC Unclassified

MSIAC
Engineering Tools and Databases

2009

Products & Services are based on staff expertise, library, and Points of Contact



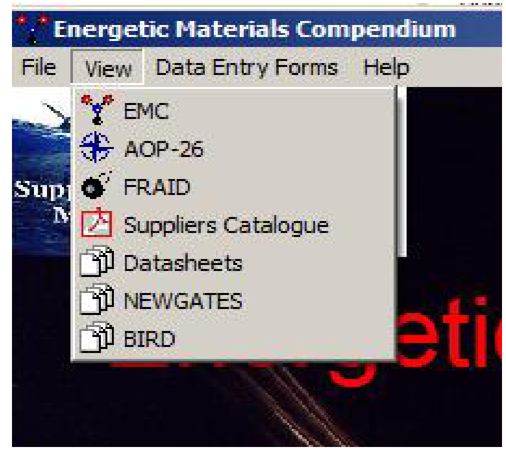
MSIAC Unclassified

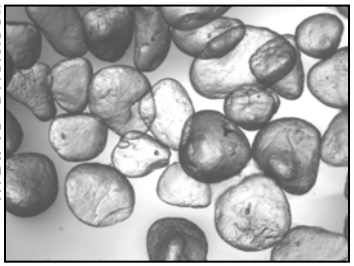
MSIAC Products - Tools & Databases

- **Energetic Materials Compendium (EMC) – 1997**
- **Mitigation Methods for Munitions (M^3) – 2000**
- **IM State-of-the-Art (IM SoA) – 2002**
- **Fragment Impact Database (FRAID) – 2002**
- **Gap Tests Information Worksheets (NEWGATES) – 2002**
- **Cost Benefit Analysis Model (CBAM) – 2003**
- **Toolbox of Engineering Models for the Prediction of Explosive Reactions (TEMPER) – 2005**
- **Safety Assessment Software (SAS) – 2005**
- **Bullet Impact Results Database (BIRD) – 2005**
- **Sympathetic Reaction Database (SYR) – 2007**
- **Cook-off Aggression Database (HEAT – Beta Version) – 2008**
- **Shaped Charge Impact Database (DARTS – May 2009) – 2009**

Energetic Material Compendium: EMC V3.4

- Current version (V3.4) released in April 2007
- Focus on adding more data and formulations (including current, in-service formulations)
  - >1000 formulations (~800 in V3.2)
  - >450 references (~350 in V3.2)
  - Double number of ingredient datasheets



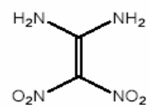


(Fox-7)

Synonyms: DADE, DADNE, 1,1-diamino-2,2-dintroethylene, 2,2-Dinitro-ethene-1,1-diamine.

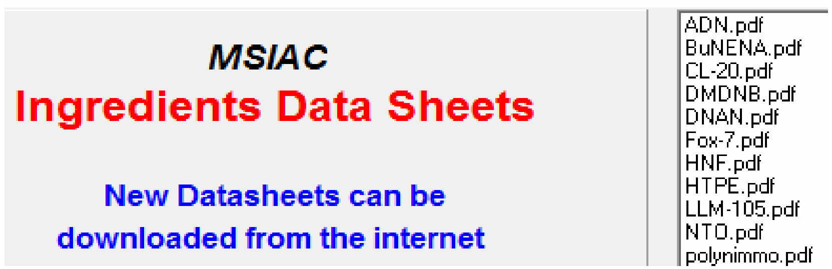
General

Fox-7 is a simple nitro-amine compound based upon ethylene. Laytpov et al first published the method to synthesis Fox-7 in the open literature in 1998[1]. Synthesis of Fox-7 involves nitration of a heterocyclic compound, commonly with mixed acid, followed by hydrolysis. Other alternative methods are available.[2]
FOX-7 exhibits a greater thermal stability and lower shock, impact and friction sensitivity than other common explosive ingredients (RDX, HMX, CL-20). Therefore, it is an interesting candidate for reduced vulnerability formulations.



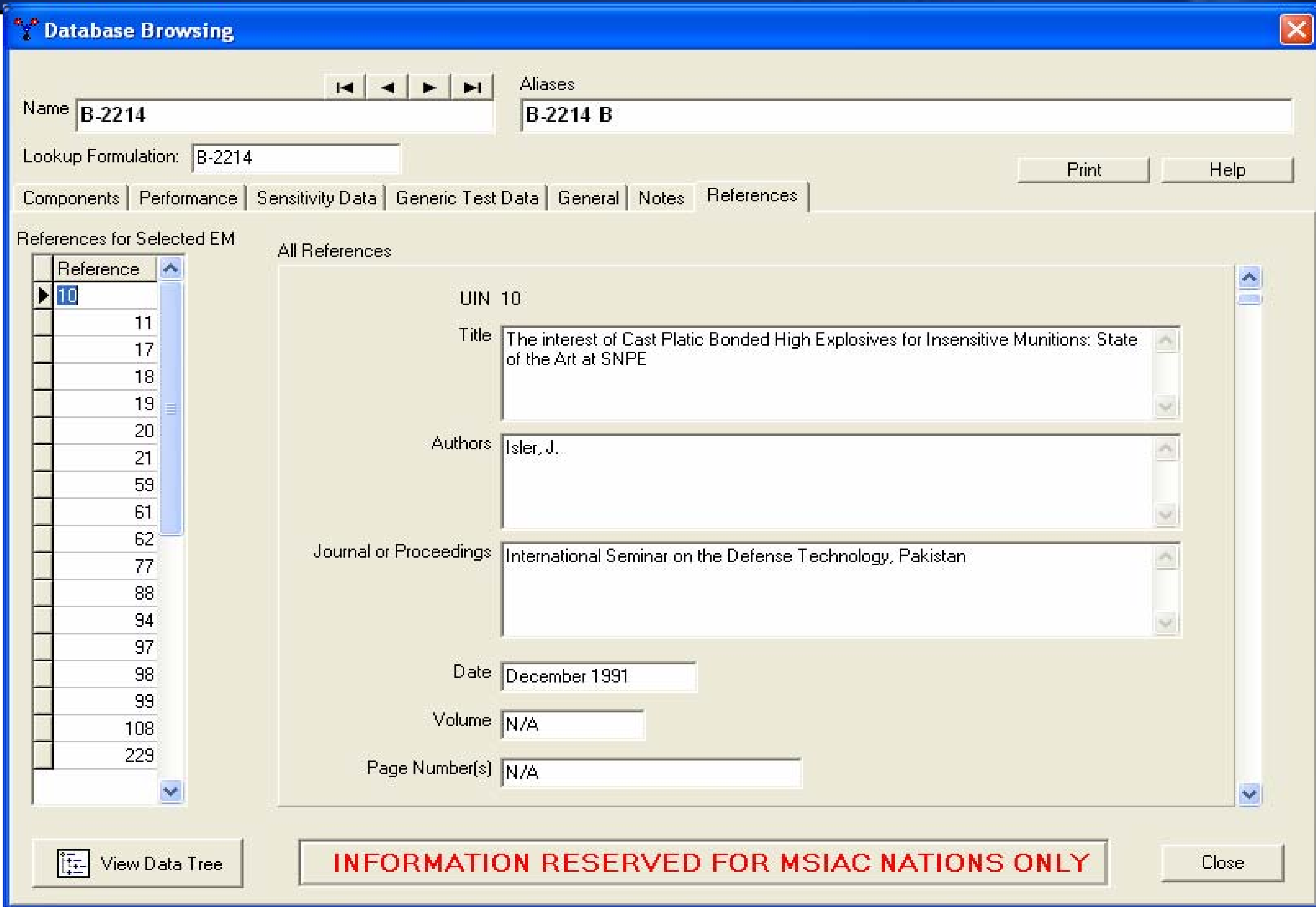
1,1-diamino-2,2-dinitroethylene (FOX-7)

- **New IM suppliers catalog**
- **Inclusion of NEWGATES and BIRD**
- **NATO AOP-26 Ed 2**
- **Updated version of FRAID**



345 'registered' users

Information Included in EMC

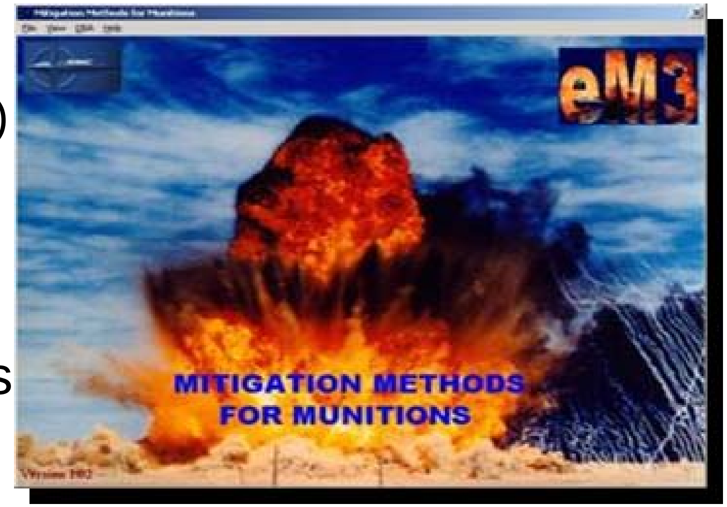


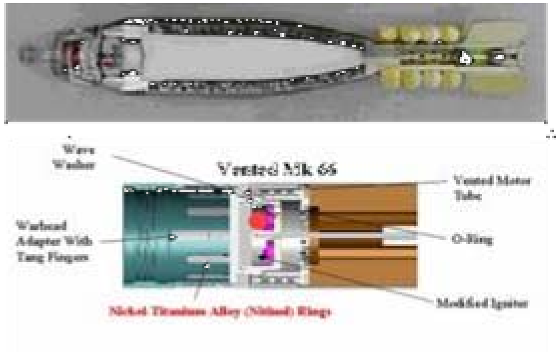
MSIAC Unclassified

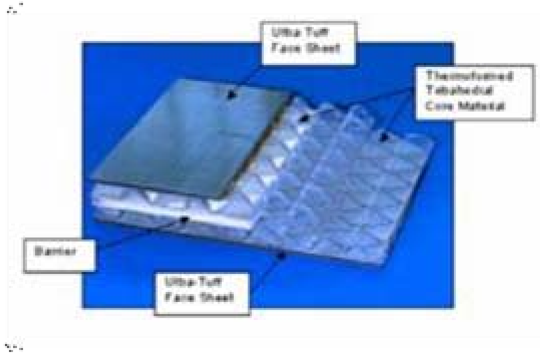
Mitigation Methods for Munitions - M^3

A compendium of technologies/techniques for mitigating the hazard presented by munitions

- Version 1.04 was released in 2005
  - Increase in the number of examples
  - More and improved quality images (75% more)
  - 20% more references used
- Enhanced search capability and key wording
- Review of all data to eliminate inconsistencies
- 61 days have been devoted to developing an updated version of M3 in 2008
- 165 registered users





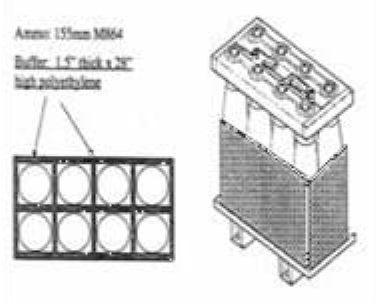


Mitigation Methods for Munitions - M^3

Sympathetic Reaction Of Adjacent Munitions

Search In M^3 For Potential Design Solutions

Input	Output
Input Component	MUNITION
Input Configuration	PACKAGED
Input Threat	SYMPATHETIC REACTION



Mitigation Methods for Munitions - M^3

General Data Access

Print

Method Description

Using buffers to mitigate shock/impacts and prevent sympathetic detonation (storage facilities or containers) .

General Information On Method | Additional Information | Specific Examples | References

Example 9 of 18
(For the method shown above)

Specific Example Description

Use of pumice as a buffer material. Pumice is a foamed volcanic glass (also defined as a white volcanic rock with no odour) that comes from granitic volcanoes. Pumice is a relatively lightweight, porous, shock absorbing material which can be mixed with a binder to provide a castable composite. It can be used to absorb the dynamic shock of an explosion and prevent sympathetic detonation of adjacent munitions. A series of tests were conducted on a variety of munitions (155-mm Comp B filled projectiles, MK-82 and MK-84 bombs) to evaluate the feasibility of using a pumice-filled container as a barrier to prevent sympathetic detonation and propagation. Most of the large tests were conducted using pumice in its natural form with no bonding material. The munitions were placed inside a container and surrounded by pumice. When a bonding agent was used, the agent served to shape the pumice and hold it in place within the container. Both methods proved effective for preventing sympathetic detonation. [47] [220]

References for the Selected Example

47

220

Click to View details

FRAgment Impact Database - FRAID

- Large fragment impact database (~1700 results)
- Wide range of
  - explosive compositions
  - munitions
  - tested parameters

FRAID

Fragment Impact Database

Version 1.8

NATO OTAN

MSIAC Supporting Munitions Safety

Problems/Questions: MSIAC or Pierre-François Péron

Phone: +32-2-707-5416 or +32-2-707-5426

Email: msiac@msiac.nato.int

or p-f.peron@msiac.nato.int

2007

Select your Explosive & Click on it

SYSTEMS

REFERENCES

MSIAC would like to acknowledge the contribution of the following organizations

DOSG DEFENCE ORDNANCE SAFETY GROUP

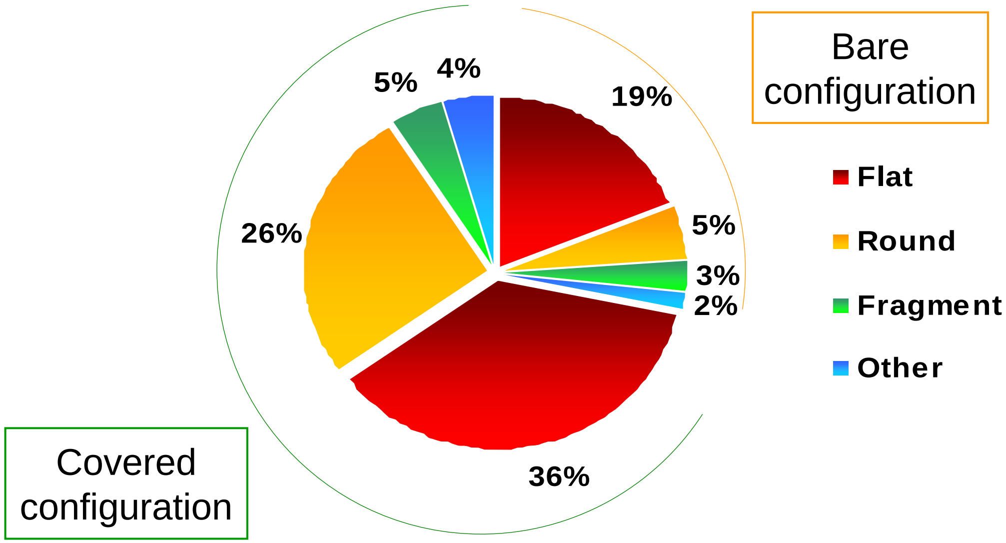
MINISTÈRE DE LA DÉFENSE DGA

V1.8 released in December 2007

Version	Number of compositions	Number of results	Number of references
V1.8	86+Systems	1716	136

Fragment Impact Database - FRAID

- Tests:
  - Scale 1 (Full Scale)
  - Small scale
  - Numerical simulations
- Covered and bare configurations
- Different types of impactors
- Variation in angle of incidence

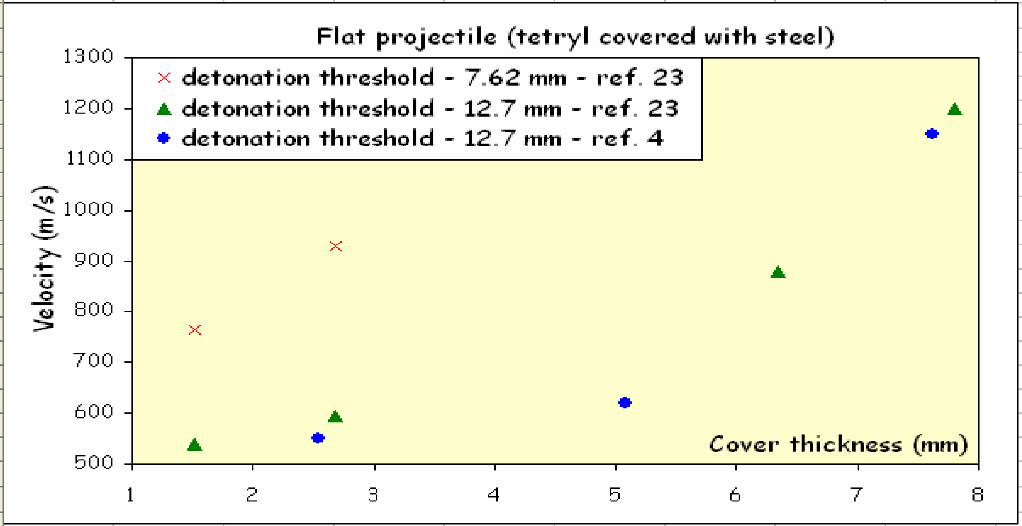


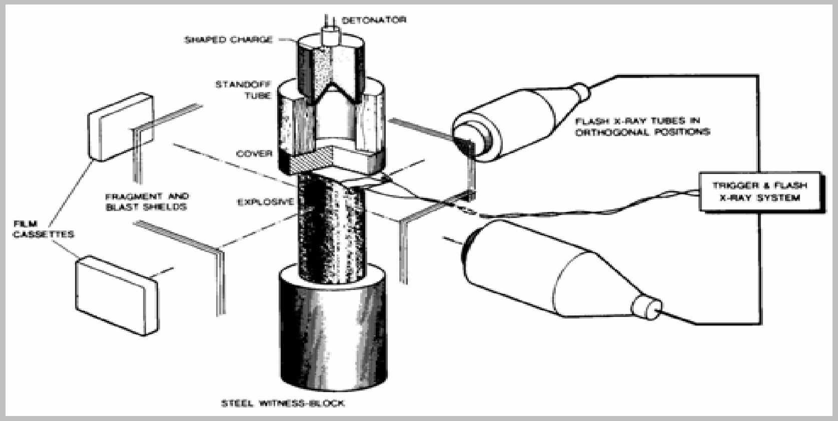
FRAID Datasheet Examples

TETRYL

Steel

EXPLOSIVE			COVERING/CASING				PROJECTILE					RESULTS		
density (g/cm^3)	process	state	thickness (mm)	diameter (mm)	length (mm)	nature	shape	nature	incidence (°)	velocity (m/s)	diameter or side (mm)	(detonation no detonation type III, IV, V, XDT, ...)	REMARKS	REFERENCES
1.5	porous	solid	2.54	-	-	-	flat	steel	0	550	12.7	detonation threshold	Data from reference 109	4 109
			5.08							620	12.7	detonation threshold		
			7.62							1150	12.7	detonation threshold		
1.54	-	solid	1.52	76	76	steel	flat	steel	0	766	7.62	detonation threshold	6.4 mm thick brass casing Data used for the determination of Jacob-Roslund model parameters	23
			2.69							929	7.62	detonation threshold		
1.54	-	solid	1.52	76	76	steel	flat	steel	0	539	12.7	detonation threshold	6.4 mm thick brass casing Data used for the determination of Jacob-Roslund model parameters	23
			2.69							595	12.7	detonation threshold		
			6.35							878	12.7	detonation threshold		
			7.8							1200	12.7	detonation threshold		
1.48	pressed	solid	136	38	< 100	-	shape charge jet	copper	0	3500	1.5	detonation threshold	MRL 38 mm shaped charge Bow shock initiation	21 (see below)





Reference 21

Bare | Steel

Bullet Impact Results Database : BIRD

- Current Version (V1.2) released in December 2007
- Large database of BI results (>2300)
  - wide range of composition
  - wide range of systems
  - fully searchable
- Comes with a Generic Testing Vehicle Database

Version	5.56mm	7.62mm	12.7mm	14.5mm	20mm	25mm	30mm	Ref.	
V1.2	21	1194	1035	2	38	0	46	141	2336

SYmpathetic Reaction Database - SYR

- Excel database
- > 650 results
- Wide range of
  - explosive compositions
  - munitions / barriers
  - tested parameters
- Fully searchable

SYR

SYmpathetic Reaction Database

Version 1.2

NATO OTAN

MSIAC Supporting Munitions Safety

Problems/Questions: MSIAC or Pierre-François PERON

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or p-f.peron@msiac.nato.int

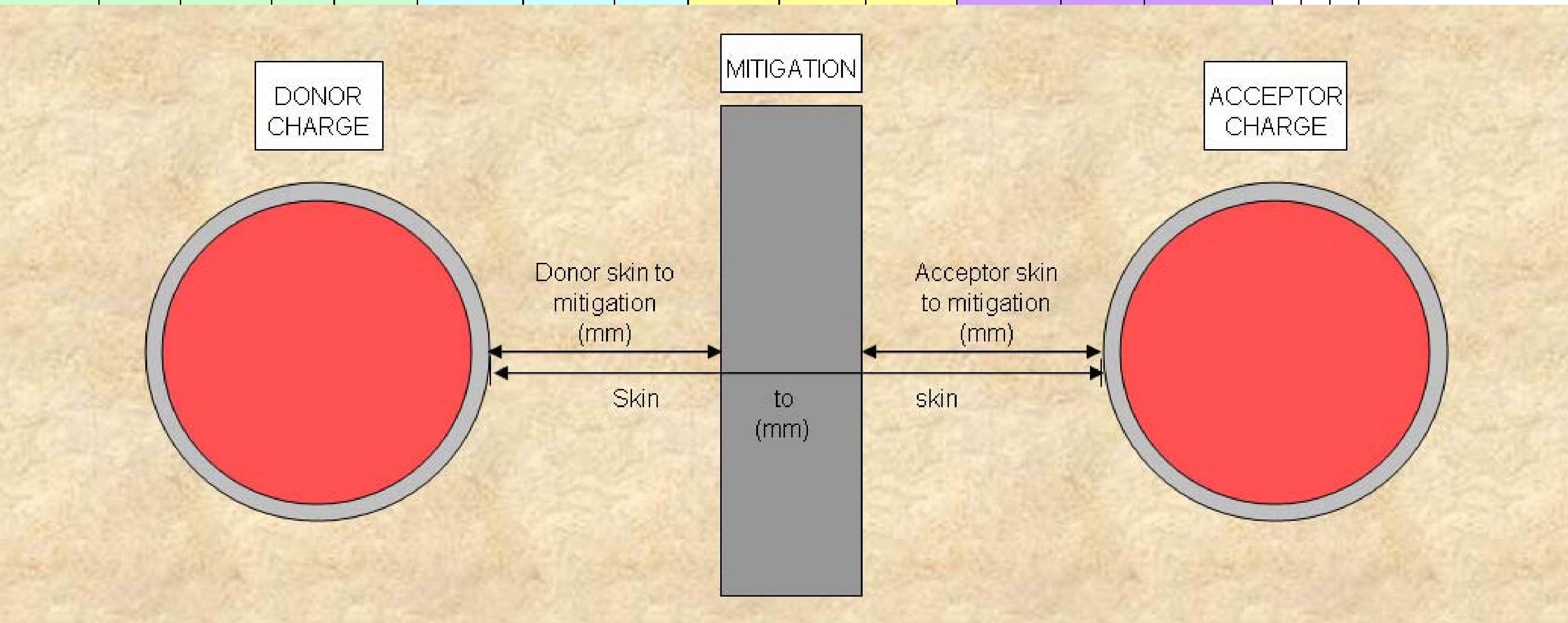
2008

SYR v1.2 released in December 2008

Version	Number of compositions	Number of results	Number of references
1.2	101	670	109

SYR – Database Content

Row	Munition	Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (mm)	Case Material	Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Initiation Mechanism	Reaction Type	Configuration	References			General Comments
	Donor (D) and Acceptor (A) Charge Features						Mitigation			Test Set up			Results			Information			
41	GTU	P (D																	...ce on sympethetic ...lts
42	GTU	P (AI																	...ce on sympethetic ...lts
43	GTU	P (D																	...ce on sympethetic ...lts
44	GTU	P (D																	...ce on sympethetic ...lts
45	GTU	P (D																	...ce on sympethetic ...lts
60	105 mm M1 shell	Co Pe																	...high and 203 mm ...tor (confinement)
76	4.5" N36	Ro																	...ooster ...osite side to donor ...in the acceptor
102	60 mm MAPAM	P																	...c box (6 mortars) ...ptor - 1 diagonal ...nert ...ed on drawings
103	LU-211M	X		8						113			DSDT		Unbuffered		a	b	...configuration ...acceptors Distance measured on a picture
104	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a	15 b	16 rounds in a pallet configuration 1 donor and 2 active acceptors inside the pallet Distance measured on a picture

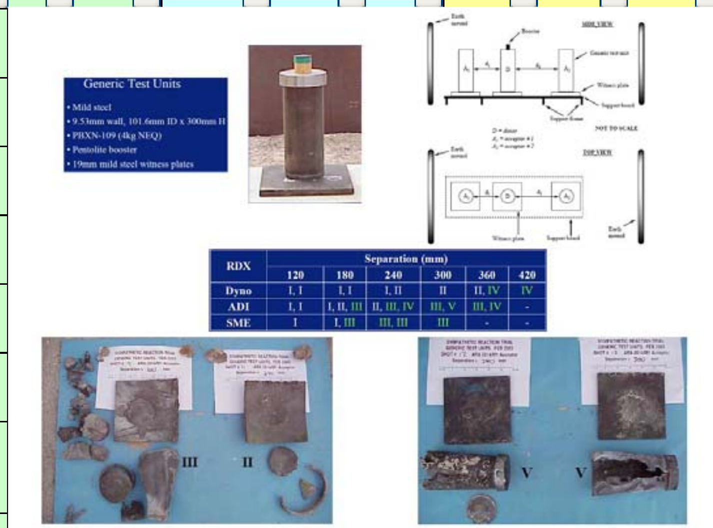


Front Page | DATABASE | Test Setup Diagram | References

MSIAC Unclassified

SYR – Database Content

Row	Munition	Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (mm)	Case Material	Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm³)	Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Initiation Mechanism	Reaction Type	Configuration	References			General Comments
	Donor (D) and Acceptor (A) Charge Features						**Mitigation**			**Test Set up**			**Results**			**Information**			
41	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	II, IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
42	GTU	PBXN-109 (ADI RS-RDX)	120.66	9.53									SDT	III, IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
43	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	IV	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
44	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	V	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
45	GTU	PBXN-109 (Dyno RDX)	120.66	9.53									SDT	V	One on One Unbuffered	6	4		Evaluation of RS-RDX influence on sympethetic reaction results
60	105 mm M1 shell	Comp B (D) Pentolite (A)	105	17-10.2-10.5									SDT	I (x1) ND (x1)	One on One Buffered	56			Polyethylene plate 510 mm high and 203 mm wide Steel plate behind the acceptor (confinement)
76	4.5" N36	Rowenex 1100	114.3	-									Undefined	-	One on One Buffered	9			Rowanex 3601 booster Shell burst open one the opposite side to donor No fragment penetration in the acceptor
102	60 mm MAPAM	PBXN-110	60	10	153	resin and ϕ 4 mm steel spheres	-	-	-	indicated but few mm for adjacent			Undefined	IV	One on Many Buffered	14	14 a		Test performed in the logistic box (6 mortars) 1 donor - 1 adjacent acceptor - 1 diagonal acceptor - 3 inert Charge features measured on drawings
103	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a	15 b	8 rounds in a half pallet configuration 1 donor and 2 active acceptors Distance measured on a picture
104	LU-211M	XF 13 333	155	16.4 15 8	560	Steel	-	-	-	35 113			SDT DSDT	IV	One on Many Unbuffered	15	15 a	15 b	16 rounds in a pallet configuration 1 donor and 2 active acceptors inside the pallet Distance measured on a picture

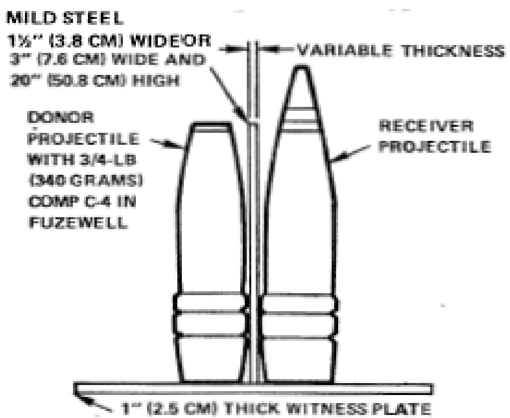


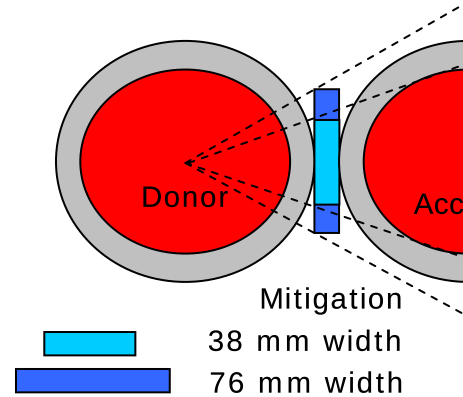
RDX	Separation (mm) 120	180	240	300	360	420
Dyno	I, I	I, I	I, II	II	II, IV	IV
ADI	I, I	I, II, III	II, III, IV	III, V	III, IV	-
SME	I	I, III	III, III	III	-	-

Front Page | DATABASE | Test Setup Diagram | References

SYR – Application Example

- **Influence of mitigation width on munition response**
  - 127 mm US Navy shells filled with Composition A3
  - Steel mitigation - 38 mm or 76 mm width
  - Shell response evaluation for various mitigation thickness





Lateral dimensions (mm)	Thickness (mm)	Number of detonation results/ Number of tests
38 mm	3	0/4
	6	0/1
	9.5	0/1
76 mm	3	2/3
	6	2/4
	9.5	0/3

Shaped Charge Impact Database - DARTS

- Excel database
- Additional databases on
  - Shaped charges
  - Generic test units
- Pictures describing the setup and the results for most reported tests
- Fully searchable

DARTS

Database of Ammunition Reaction Trials to Shaped Charge Aggression

Version Beta

NATO OTAN

MSIAC Supporting Munitions Safety

Problems/Questions: MSIAC or Pierre-François PERON

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Email: msiac@msiac.nato.int

or p-f.peron@msiac.nato.int

2008

V1.0 to be released in May 2009

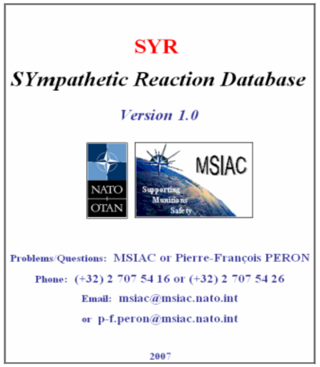
Version	Number of compositions	Number of results	Number of references
Beta	18	50	10

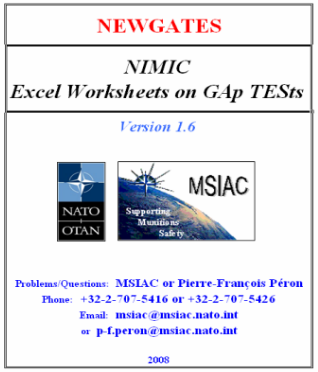
MSIAC Unclassified

Database Searching Tool

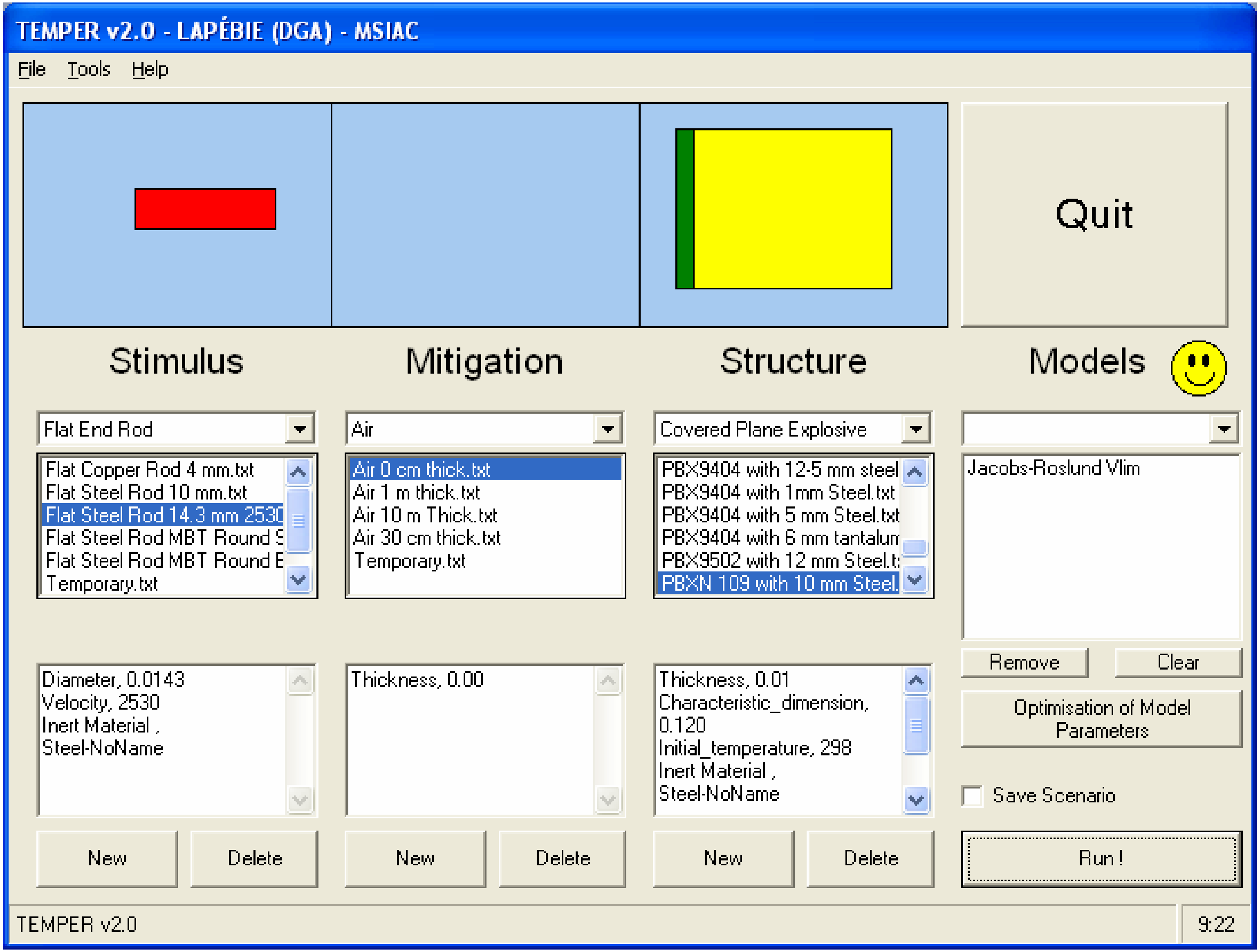
- Available databases for all IM tests in 2009
- Another database related to gap test results (NEWGATES)
- All databases in Excel format with similar architectures

- Next step
  - Development of a search tool to gather quickly information available in all the databases
  - Search with one or several keywords, headings
  - Results in an Excel workbook (one or several worksheet per database)



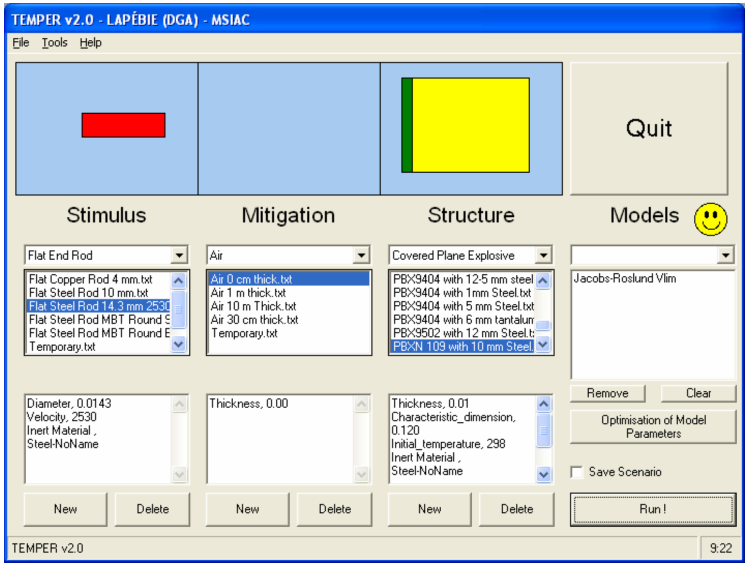


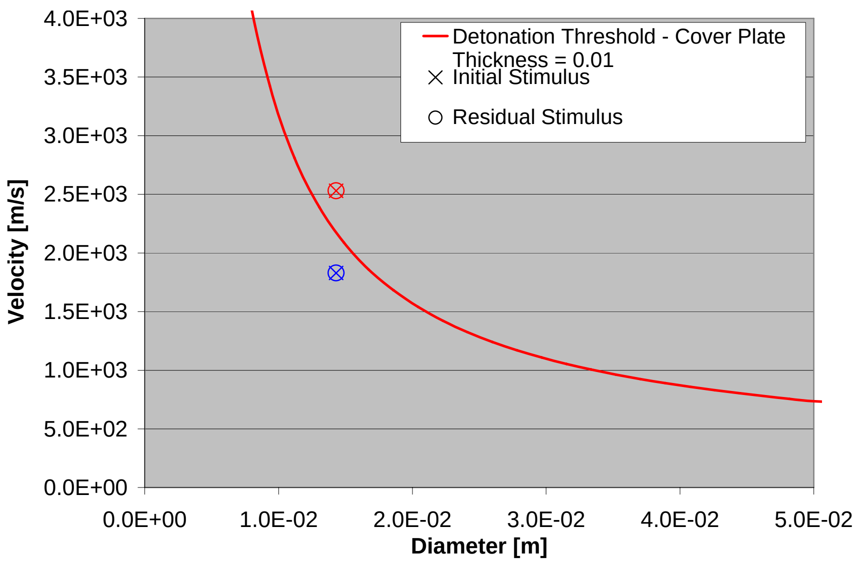
Toolbox of Engineering Models for the Prediction of Explosive Reactions (TEMPER)



TEMPER

- MSIAC in conjunction with DGA (French MOD) have been offering access to a French software program called TEMPER
- A library of empirical and analytical models dedicated to ammunition safety. It has the potential to become a reference tool if resources allocated
- MSIAC acts as a focal point to ensure coherence and availability. Users can develop custom models or enhance existing ones.
- TEMPER is flexible to afford multiple developers and therefore save time and money
- TEMPER is documented to ensure ease of further developments and ensure consistency
- TEMPER main features include
  - Library of threats, models and parameters to run the models
  - Ability to select threat/mitigation/structure/model
  - Ability to perform parametric or stochastic simulation:
  - Ability to draw curves and save results

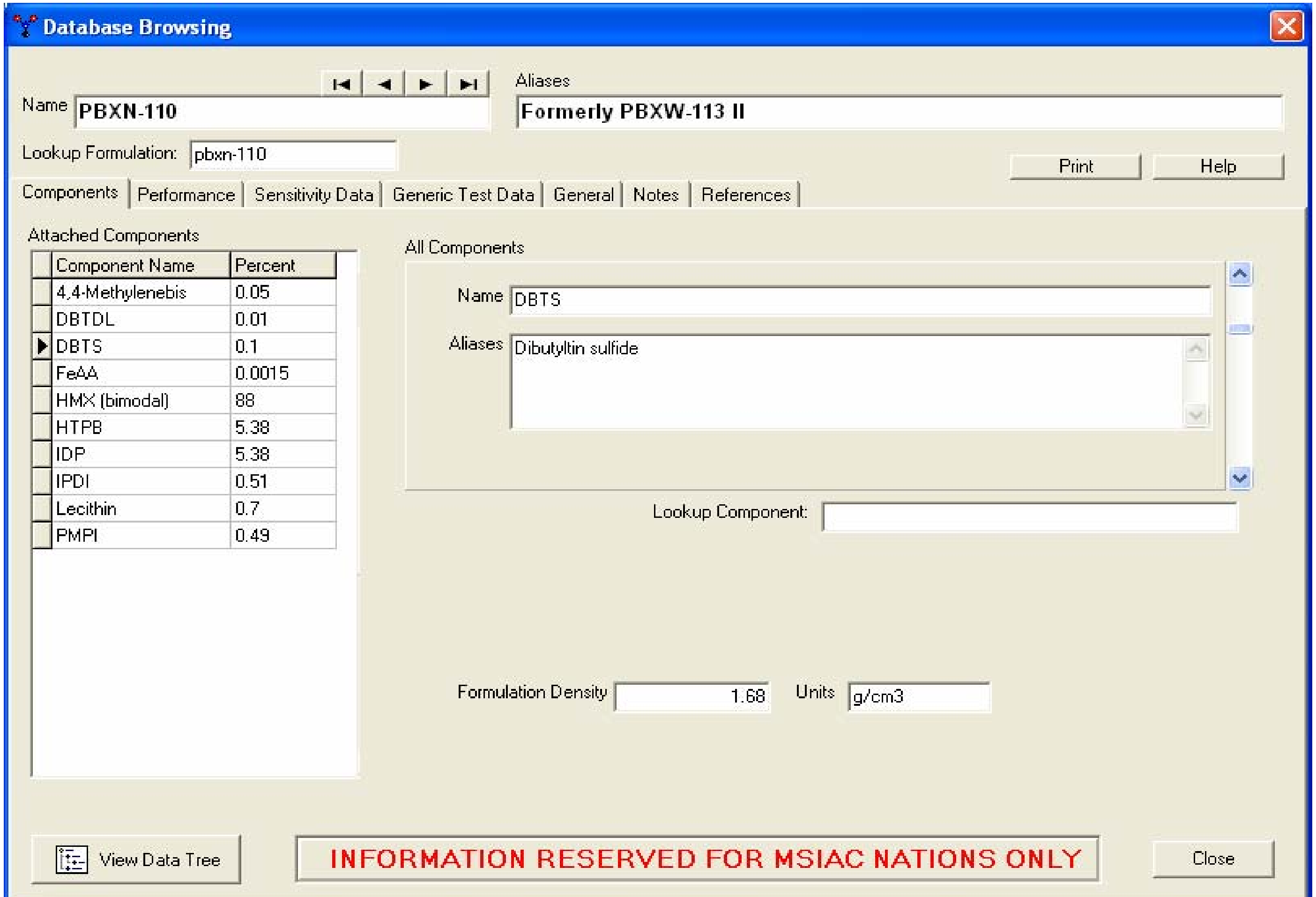




Example of Database Use for Engineering Work

- PBXN-110 has been selected as a candidate for the development of a new warhead with a steel envelop.
- Which IM level can be achieved with this explosive?

EMC



Database Browsing

Name: PBXN-110

Aliases: Formerly PBXW-113 II

Lookup Formulation: pbxn-110

Print | Help

Components | Performance | Sensitivity Data | Generic Test Data | General | Notes | References

Attached Components

Component Name	Percent
4,4-Methylenebis	0.05
DBTDL	0.01
DBTS	0.1
FeAA	0.0015
HMX (bimodal)	88
HTPB	5.38
IDP	5.38
IPDI	0.51
Lecithin	0.7
PMPI	0.49

All Components

Name: DBTS

Aliases: Dibutyltin sulfide

Lookup Component:

Formulation Density: 1.68 Units: g/cm3

View Data Tree

INFORMATION RESERVED FOR MSIAC NATIONS ONLY

Close

Example of Database Use for Engineering Work

MSIAC Unclassified

NEWGATES

Number of available gap tests results	508			SSWaterGT results			ISGT results				NOL-LSGT results			
INTRO Substance	rho0 [g/cm3]	C0 [km/s]	S	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)	number of cards	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)	number of cards	gap length (mm)	Incident Initiation Pressure (Gpa)	Critical Initiation Pressure (Gpa)
PBXN-110	1.680	2.470	1.270		-	-			-	-	154	39.12	3.67	4.15
PBXN-110	1.680	2.470	1.270	17.0	2.3	3.21			-	-	178	45.21	2.69	3.06
PBXN-110	1.600	1.905	3.700	15.0	2.7	4.01			-	-			-	-
PBXN-110 (Dyno RS-HMX)	1.650	1.905	3.700	11.0	3.6	5.47			-	-			-	-
PBXN-110 (Dyno)	1.650	1.905	3.700		-	-			-	-	172	43.69	2.90	3.61
PBXN-110 (Bofors)	1.660	1.905	3.700		-	-			-	-	150	38.10	3.87	4.94
PBXN-110 (HAAP)	1.670	1.905	3.700		-	-			-	-	159	40.39	3.43	4.35
PBXN-110 (HAAP- 6 months old)	1.620	1.905	3.700		-	-			-	-	156	39.62	3.57	4.49
PBXN-110 (Bofors- 6 months old)	1.620	1.905	3.700		-	-			-	-	158	40.13	3.48	4.36
PBXN-110 (Dyno- 6 months old)	1.640	1.905	3.700		-	-			-	-	173	43.94	2.86	3.55

SYR

	Donor (D) and Acceptor (A) Charge Features					Mitigation			Test Set up			Results			Information		
Munition	Energetic Material	External Diameter (mm)	Case Thickness (mm)	Case Length (mm)	Case Material	Mitigation Material	Mitigation Thickness (mm)	ρ (g/cm^3)	Distance Donor Skin to Acceptor Skin (mm)	Distance Skin of Donor to Mitigation (mm)	Distance Skin of Acceptor to Mitigation (mm)	Configuration	Initiation Mechanism	Reaction Type	References		General Comments
60 mm MAPAM	PBXN-110	60	10	153	Plastic resin and ϕ 4 mm steel spheres	-	-	-	Not indicated but close			One on Many Buffered	Undefined	IV	14	14 b	Mortars in their logistic container Charge features measured on drawings

BIRD

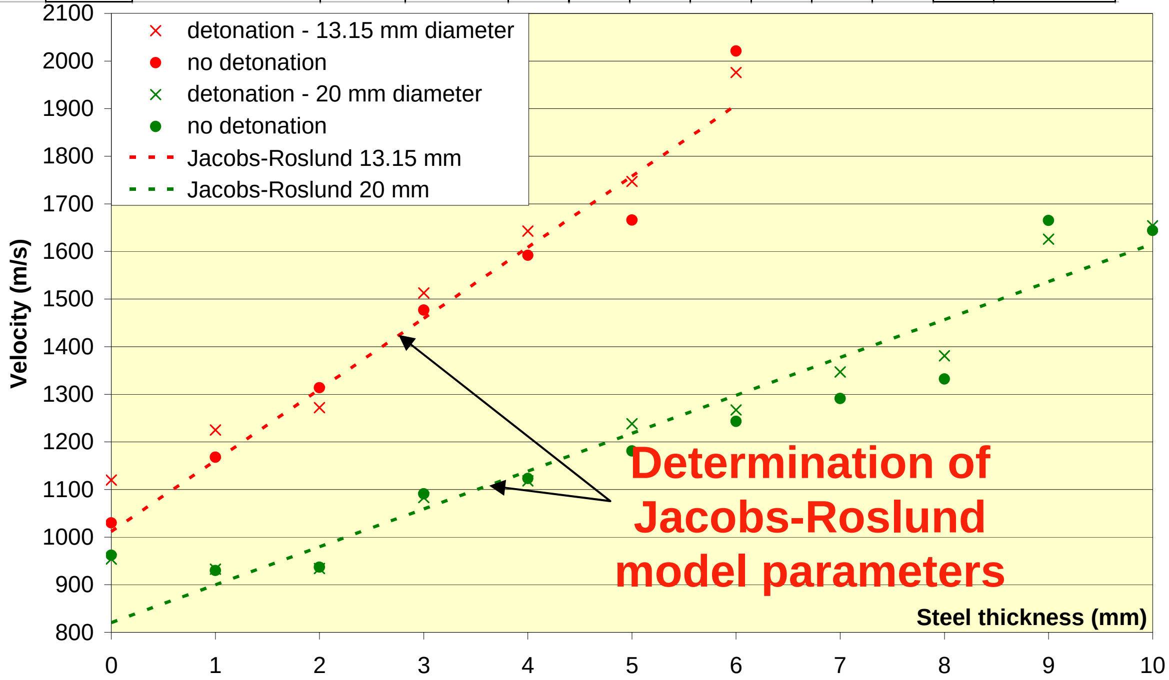
12.7 mm bullet impact																						
TESTED SYSTEM									THREAT						TEST	REACTION LEVEL						
System Designation	Country of Test	Tested Item	Config	Aim point	Aim Point Design.	Energetic Material at Aim Poin	Case thickness at Aim Point (mm)	Case Material at Aim Poi	Design.	Vo (m/s)	Firing range (m	V impact (m/s)	Burst or Sing	Burst Timing (ms	Proc.	Type I	Type II	Type III	Type IV	Type V	NR	Other
2,75 inch Rocket (HYDRA-70)	US	W	B	Warhead Fuze Booster	MK 146 Mod 0 MK 435 Mod 0	PBXN-110 PBXN-7	-	Steel	AP	-	-	850 +/-60	B	-	MIL-STD-2105B					1		
2,75 inch Rocket (HYDRA-70)	US	W	B	Warhead Center	MK 146 Mod 0	PBXN-110 (Cast)	-	Steel	AP	-	-	850 +/-60	B	-	MIL-STD-2105B					1		
60mm Mortar Shell	CH	AUR	B	Warhead Center	MAPAM	PBXN-110	-	Steel	AP	-	-	850 +/-60	S	-	MIL-STD-2105B					2		
60mm Mortar Shell	CH	AUR	B	Warhead Booster	MAPAM	PBXN-110 PBXN-5	-	Steel	AP	-	-	850 +/-60	S	-	MIL-STD-2105B					2		
UN Steel Tube	NW	GTU	B	Center	-	PBXN-110	4	Steel	AP M2	840 +/-40	-	-	S	-	EIDS 7(d)(i) Test						3	

Example of Database Use for Engineering Work

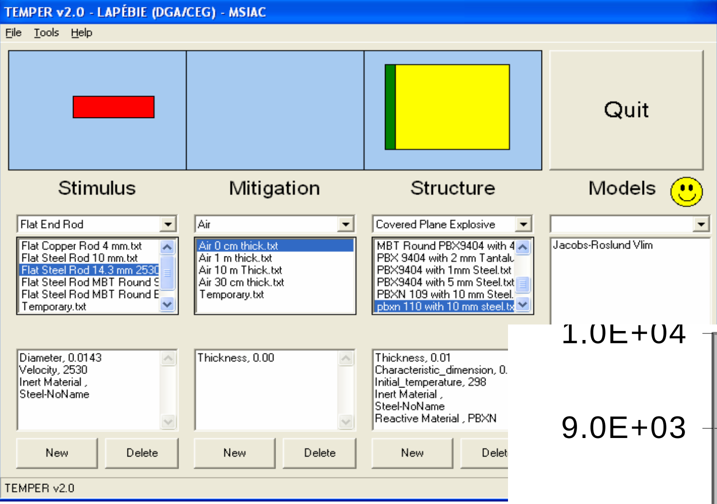
EXPLOSIVE			COVERING/CASING				PROJECTILE					RESULTS	REMARKS	REFERENCES
density (g/cm³)	process	state	thickness (mm)	diameter (mm)	length (mm)	nature	shape	nature	incidence (°)	velocity (m/s)	diameter or side (mm)	(detonation no detonation type III, IV, V, XDT,		
99.6% TMD	cast-cured	solid	4.06	55.12	199.90	steel	conical 140° (16 g)	steel	0	1829	12.7	type IV	Test according to MIL-STD-2105 B (alternate test procedure #1) Target: UN steel pipe for EIDS bullet impact test Worst result over 2 tests Shaped charge application	46 47 48 (see below)
-	cast-cured	solid	5.1	76	-	steel	conical 160° (18.6 g)	steel	0	2050	14.3	type V	Test performed to replace the explosive composition of the HYDRA-70 rocket STANAG 4496 fragment	128 (see below)
										2266	14.3	type I		
-	-	solid	9.5	203.2	406.2	steel	≤ 2 cubes	steel	0	2530	12.7	type III (x3)	Test conducted in accordance with MIL-STD-2105 B Modified Naturally Fragmenting Test Unit (NFTU) used as a target	123

SYSTEM INFORMATION							THREAT	TEST	REACTION LEVEL								
System Name	System Designation	Clas.	Tested Item	Tested Item Design	Caliber (mm)	Energetic Material	Burst or Single	Proc.	Type I	Type II	Type III	Type IV	Type V	NR	Other	Ref	Velocity (m/s)
60mm Mortar	MAPAM	GMA	AUR	-	60	PBXN-110 PBXN-5	S	2105B					1			70	
AMRAAM	AIM-120A	AAW	F	WDU-41/B Mk 80 Mod 0	127	PBXN 110 PBXW-11	B	2105B					2			100	2504 2540

FRAID

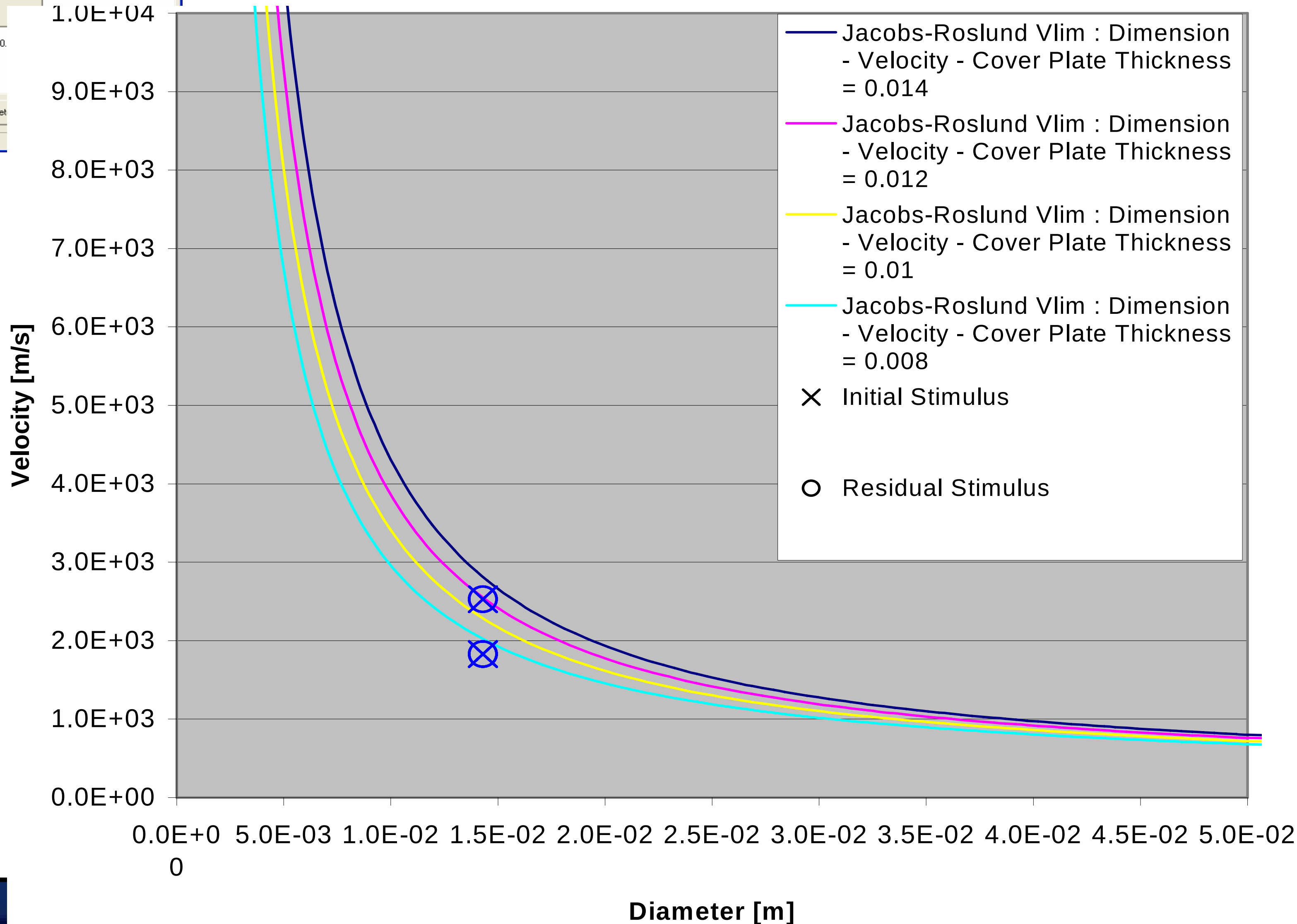


Example of TEMPER Simulation Result with FRAID Input Data



Use of Jacobs-Roslund model parameters to estimate fragment detonation threshold

TEMPER



M Munitions
S Safety
I Information
A Analysis
C Center

Web site http://www.msiac.nato.int

e-mail msiac@msiac.nato.int

Safety Assessment Software - SAS

- SAS is a tool for the development of Safety and Suitability for Service assessment of munitions. It assists the user to:
  - define the common threats to the munition
- The life cycle of the munition is developed using AOP 15 Annex A
- Environmental constraints are input based upon the user requirements
- SAS will identify relevant standards and make them available
- A report of all identified trials documentation can be exported in Word Excel or TXT formats.
- An electronic document database of international (UN, NATO) and several national standards applicable to munitions is included.

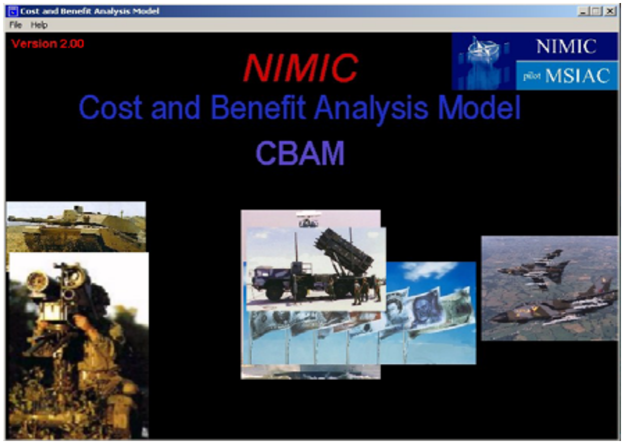
Current version released January 2007

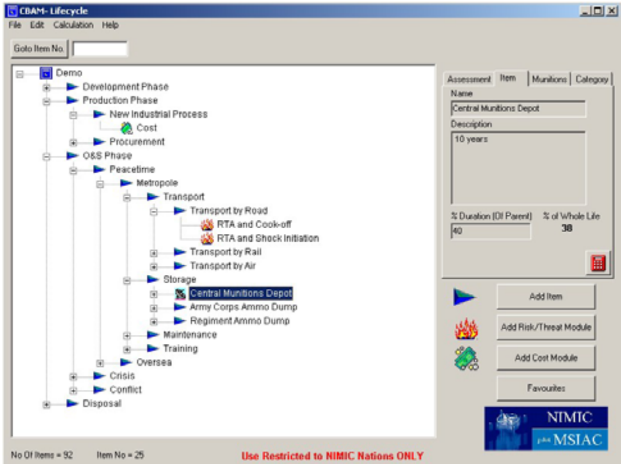
MSIAC Unclassified

Cost Benefit Analysis Model: CBAM v2.0

A tool to help calculate the cost differences of introducing IM into service

- It can also be used to calculate the cost of ownership of a munition
- CBAM calculates cost differences by:
  - Aiding in the creation of a life cycle for a munition type
    - Life-cycle Tree creation component
  - Providing a structured method for compiling cost data
    - Modules to account for cost differences arising from:
      - **Risk Assessment & Direct cost**
  - Calculates cost by means of a Monte Carlo Simulation
    - Takes into account the uncertainties





Total Life Cycle Management Value Stream Deployment Project Overview

April 7, 2009

Mr. Gale E. Heaivilin

Headquarters U. S. Marine Corps
Marine Corps Business Enterprise Office
gale.e.heaivilin@usmc.mil
(703) 695-5768

Agenda

- Background
- The Situation
- Project Initiation
- Value Stream Management
- Project Overview
- Key Findings and Outputs
- Way Ahead

Background

Marine Corps leadership recognized a need to better manage the total life cycle of its weapon systems, ground equipment and materiel in order to strengthen the combat effectiveness of Marine Air Ground Task Forces.

The Situation: Problem Areas

- Sustainment Planning
- Equipment Accountability
- Data and Information Systems
- Coordination, Collaboration and Oversight

The Situation: Problem Types

- Roles, responsibilities and relationships
- Information management
- Collaboration across organizations
- Internal management controls
- Performance standards and metrics
- Cross-boundary improvements
- End-to-end process management

The Situation: Effects

- Diminished equipment readiness
- Unnecessarily high TLCM cost
- Reduced ability to manage and operate equipment
- Sub-optimal use of facilities and distribution systems

Bottom Line: Required a comprehensive, integrated solution

TLCM Project Initiation

- **Deputy Commandant for Installations and Logistics Priorities 2 and 3:**
  - **Total Life Cycle Management**
    - Increase equipment readiness through "cradle-to-grave" management of weapons systems
  - **Continuous Process Improvement**
    - Improve combat readiness through innovation
- **"…address in a comprehensive way the roles, responsibilities and policies for the TLCM Value Stream in order to optimize the effectiveness of the support it delivers to our Warfighters…"**

Ref: Deputy Commandant for Installations & Logistics Letter 4140 over LR of JAN 22 2008

USMC Value Stream Management

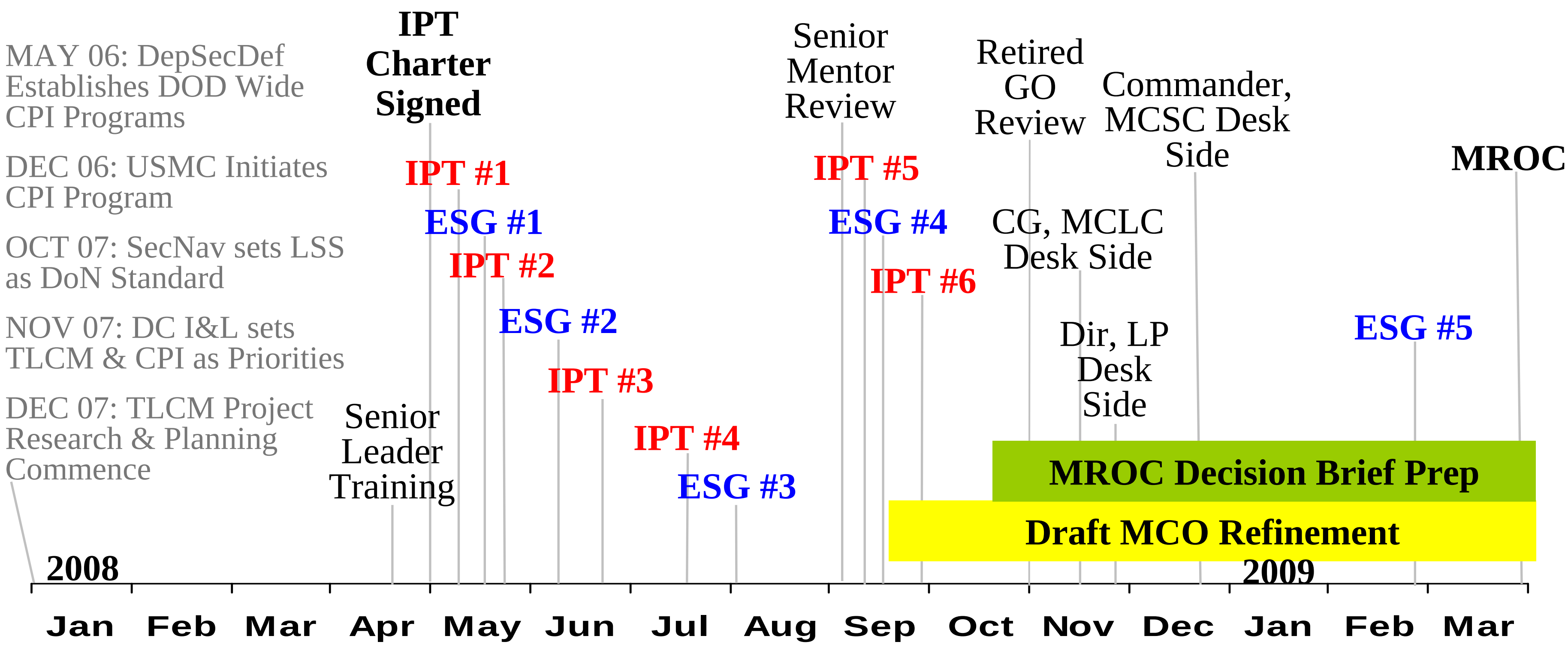
- **We are creating a system of Continuous Process Improvement -- People, processes and technologies that effectively manage production and initiatives aligned with strategic goals**
  - Improved measure-ability and visibility
  - Consistency
  - Collaborative, cross-functional ownership
  - Horizontal Value Stream Centric Strategy, Measurement and Management

- **We are not building:**
  - A Report
  - Operating Procedure Manuals
  - A Large List of Projects
  - A New Organizational Chart

Vision is cross-functional value stream members:
- Participating in strategic planning
- Reviewing output oriented performance data
- Closing and launching a stream of improvement initiatives within capacity
- Tracking improvements
- Measuring strategic progress

TLCM Project Overview

Marine Corps TLCM Project Timeline, Apr 08 – Mar 09



Legend:

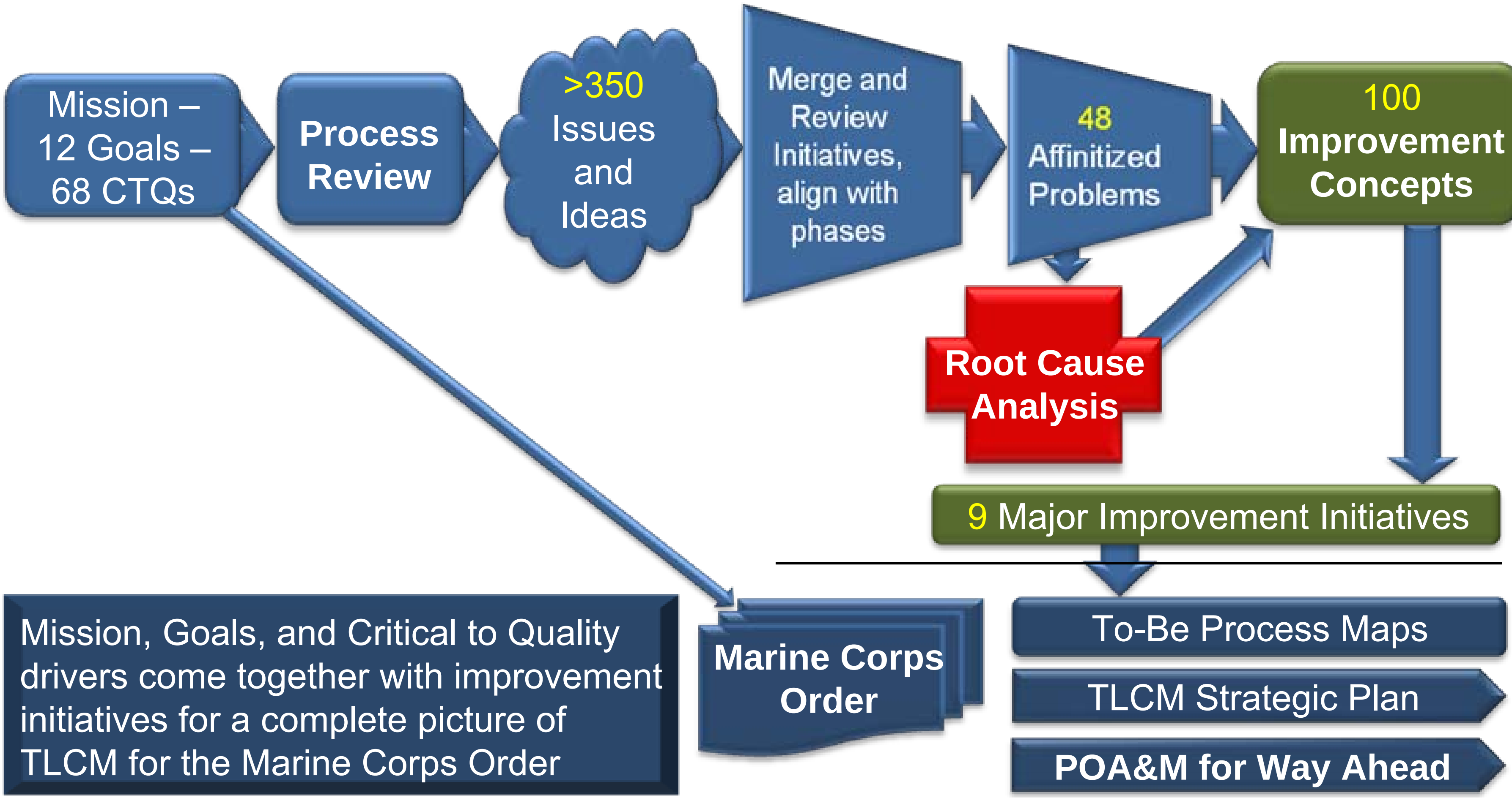
IPT – Integrated Product Team

ESG – Executive Steering Group

MROC – Marine Requirements Oversight Council

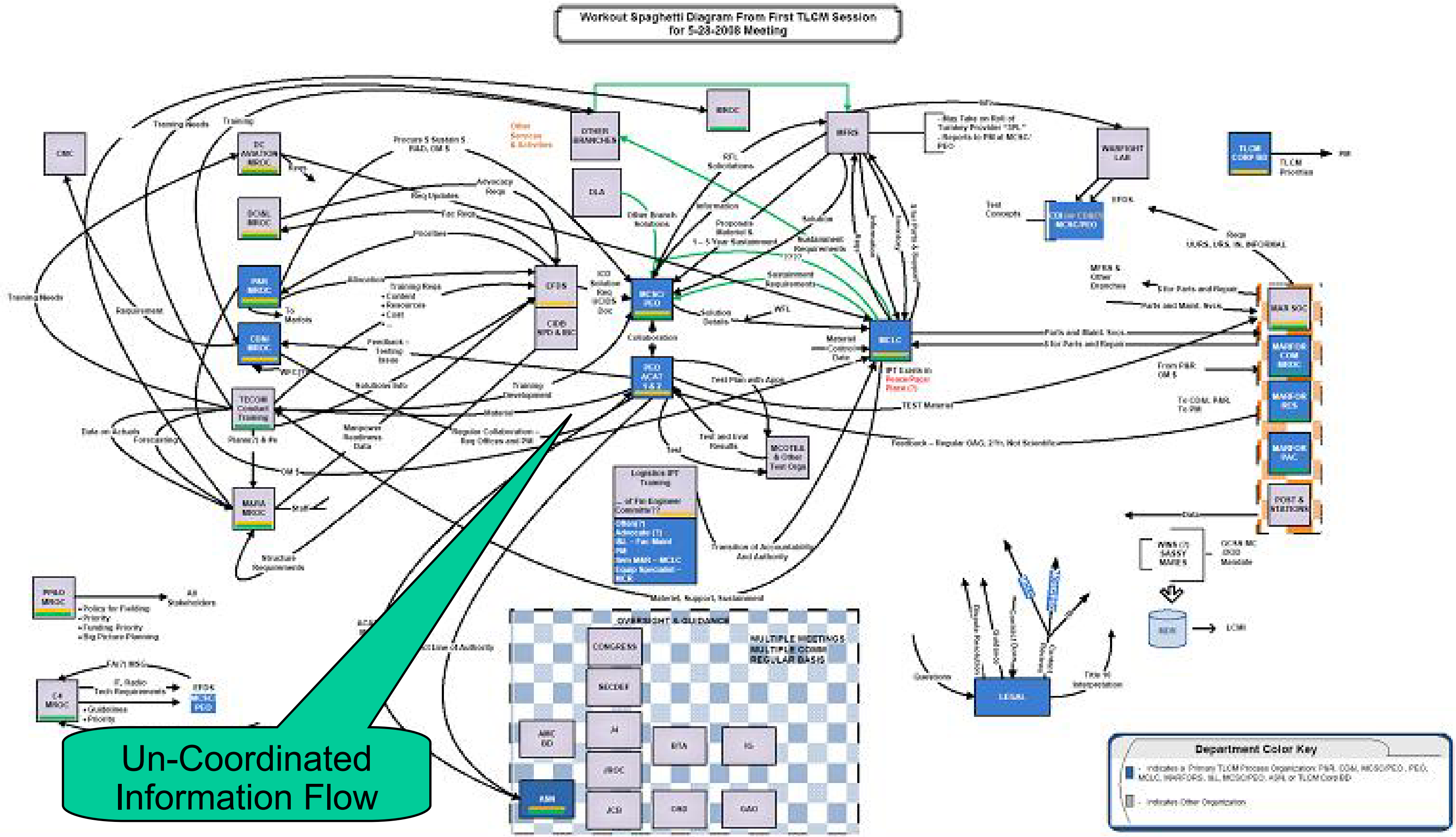
TLCM Project Overview

Work Sequence and Outputs



TLCM Project Overview

TLCM Information Flow, May 2008

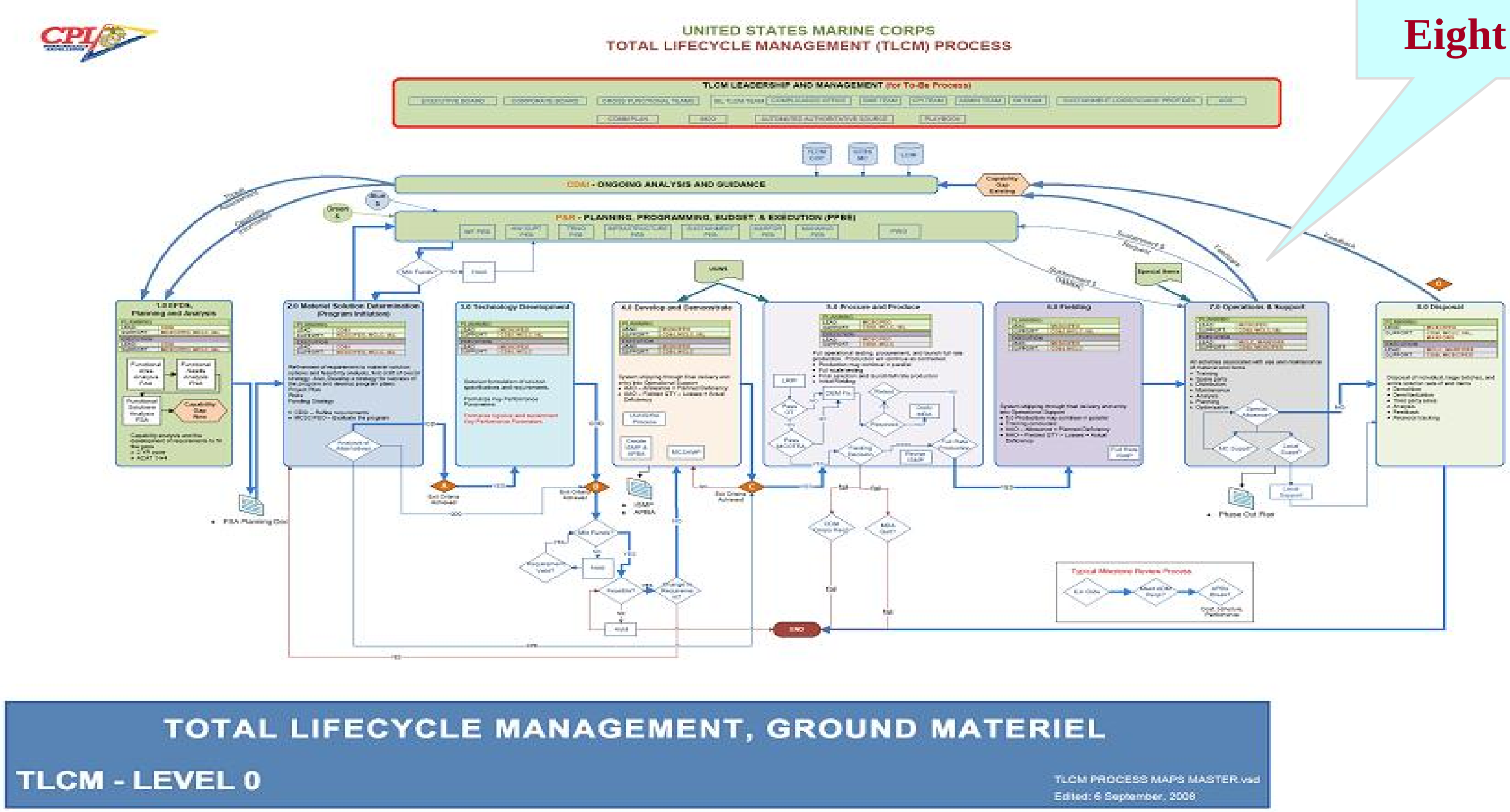


TLCM Project Overview

To-Be Process Flow (Level 0 Map), September 2008

Planning and Analysis - Materiel Solution Determination - Technology Development - Develop and Demonstrate - Produce and Procure – Fielding - Operations and Support - Disposal

Eight Phases



Key Findings and Outputs

Major Improvement Initiatives

- Communications
- Data and information
- Human resources
- Leadership and Governance
- Policy
- Process
- Technology
- Training and Education
- Quality Management

Key Findings and Outputs

TLCM Project Key Deliverables

CPI PERFORMANCE EXCELLENCE

Total Life Cycle Management Charter

Final - Signed
Date Initiated: 2 May 08
Revision Date:

- Internal Management Controls are absent or do not effectively support TLCM phases
- Full cost, standard processes, standard outputs, and performance metrics are lacking

Thus, the Marine Corps is less capable to deliver and measure combat readiness performance at all levels of the enterprise.

Goal Statement

The Marine Corps requires an over arching governance policy document that clearly defines stakeholder roles, responsibilities, organization, processes and technology. Goals of this project are:

- Define and validate stakeholder roles, responsibilities, and tasks for USMC total life cycle management process
- Craft a governance document (Marine Corps Order) that publishes TLCM policy that supports the EFDS and PPBES process
- Identify follow-on CPI opportunities that support future projects, spin-offs and process improvement initiatives

Define and validate Stakeholder roles, responsibilities, and tasks for the USMC Total Life Cycle Management process	**Complete**
Craft a governance document (Marine Corps Order) to promulgate TLCM policy that supports the Capabilities Development and Resource Allocation processes	**Complete**
Identify follow-on CPI opportunities that support future projects, spin-offs and process improvement initiatives	**Complete**

Key Findings and Outputs

Proposed Solutions

Sustainment Planning:

- √ **Plan sustainment during requirements generation and acquisition strategy**

Equipment Accountability:

- √ **Integrate reporting systems**

Data and Information Systems:

- √ **Improve data for decision making**

Coordination, Collaboration and Oversight:

- √ **Create metrics and a comprehensive reporting system**
- √ **Integrate oversight efforts**

Way Ahead

- **Align TLCM roles, responsibilities and authorities**
  - **Designate a TLCM Governance Leader**
  - **Approve TLCM Leader Authorities**
    - **Policy and planning**
    - **Information and data management**
    - **Integrated cross-functional governance**
    - **TLCM Training**
- **Review all TLCM and CPI Policies**
- **Review TLCM Training**
- **Build a TLCM Oversight Process**
- **Assess and Improve Information Management systems**
- **Improve Sustainment Planning**
- **Continue Making Process Improvements**

QUESTIONS?

Total Life Cycle Management

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Continuous Process Improvement

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USMC Improvement Methodology

U. S. Marine Corps Standard Continuous Process Improvement (CPI) Methodology: DMAIC

IDENTIFY PROBLEMS	DEFINE
DESCRIBE CONDITION	MEASURE
LIST POTENTIAL CAUSES	ANALYZE
PROPOSE SOLUTIONS	IMPROVE
PREPARE ACTION PLANS, IMPLEMENT IMPROVEMENTS	CONTROL
VERIFY RESULTS	

Long Term Implementation

Document, Communicate and Identify Replication Opportunities

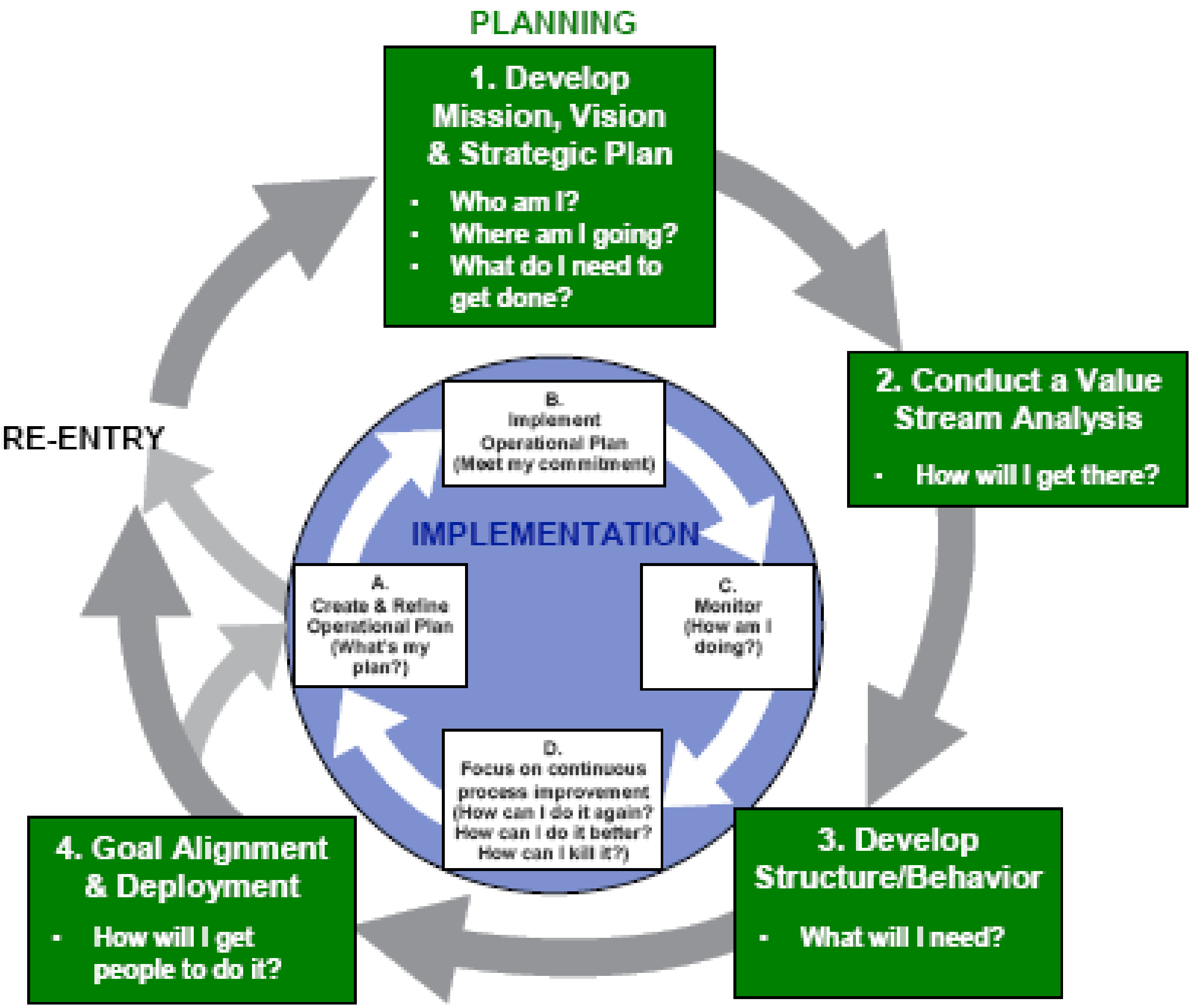
Ref: U. S. Marine Corps Continuous Process Improvement Guidebook, March 1, 2009

DMAIC Methodology Explained

Define	What exactly is (and what is not) the problem to be addressed by this project	Define prevents teams from jumping straight into solution mode
Measure	What is the true current process performance	Data is used as a benchmark for before-after comparison so benefit can be proved at end of project
Analyze	Find the root cause of the problem using process analysis and data analysis techniques	Prevents "band-aid" solutions, which never really work
Improve	Develop, validate and risk-proof a focused, innovative solution	Solution directed at proven root causes will almost always be successful
Control	Make sure the solution sticks and quantify the benefits	Solution does not "fall over" when project ends but becomes the new standard way of operating the process

Ref: www.sixsigmascotland.co.uk

DOD CPI Deployment Cycle



Ref: DOD Continuous Process Improvement Transformation Guidebook, May 2006

CPI "Musts"

1. An established infrastructure to support CPI implementation — Champion, Steering Committee, Support Team, Work Groups and Peer Groups

2. Outcome-focused goals, strategically aligned and mission related, that add customer value

3. Thorough problem Definition, Measurement, Analysis, Improvement and Control (DMAIC) within a logical methodical plan of action

4. Strong, continuously visible leadership commitment from the top that stresses and supports a culture of innovation and teamwork

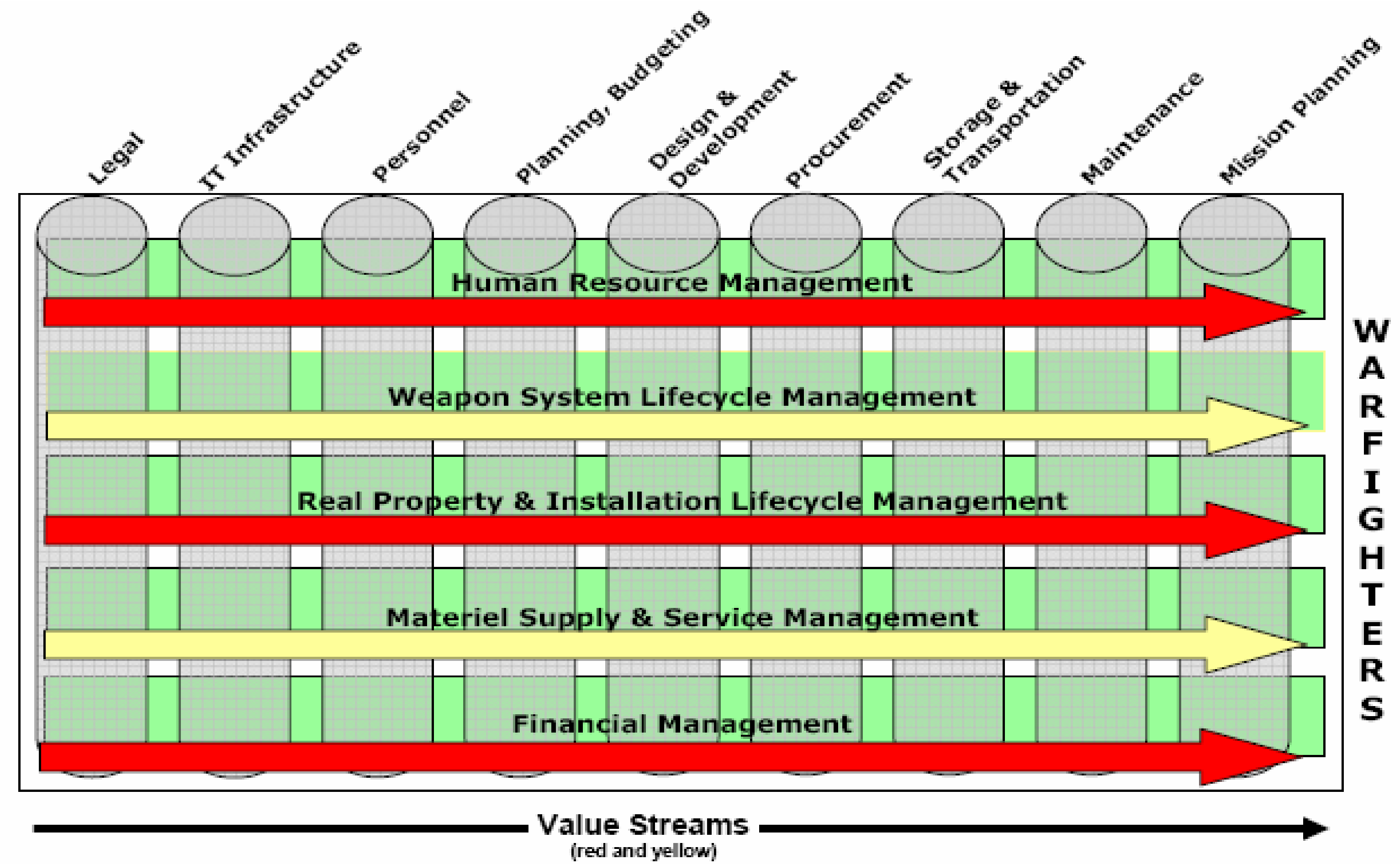
Ref: DOD Continuous Process Improvement Transformation Guidebook, May 2006

CPI Principles

1. Determine current situation using objective (fact-based) data analysis
2. Analyze problems as a variation from a known or expected standard
3. Set a goal to holistically improve the entire system and avoid sub-optimization through isolated focus on process sub-elements
4. Focus on the people, machines, and systems that add value
5. Improve processes through continuous controlled experimentation
6. Make decisions based on long-term improvement
7. Employ partnering with suppliers, customers, and other stakeholders

Ref: DOD Continuous Process Improvement Transformation Guidebook, May 2006

Value Streams and the DOD Enterprise



Ref: DOD Continuous Process Improvement Transformation Guidebook, May 2006

Marine Corps Value Streams

U. S. Marine Corps High Impact Core Value Streams

HIGH IMPACT CORE VALUE STREAM	HICVS LEADER
CAPABILITY DEVELOPMENT	DC, CD&I
TOTAL LIFE CYCLE MANAGEMENT	DC, I&L
ACQUISITION	CG, MCSC
AVIATION MATERIEL LIFE CYCLE MANAGEMENT	DC, AVN
HUMAN RESOURCE DEVELOPMENT	DC, M&RA
RESOURCE ALLOCATION	DC, P&R
INSTALLATION MANAGEMENT	DC, I&L
INFORMATION TECHNOLGY	DIR, C4/CIO
SERVICE ADVOCACY	DC, PP&O

Ref: U. S. Marine Corps Continuous Process Improvement Guidebook, March 1, 2009

Value Streams and the DOD Enterprise

USMC Business Enterprise Architecture ◆ DoD Business Enterprise Architecture

U. S. Marine Corps High Impact Core Value Streams

HIGH IMPACT CORE VALUE STREAM	HICVS LEADER
CAPABILITY DEVELOPMENT	DC, CD&I
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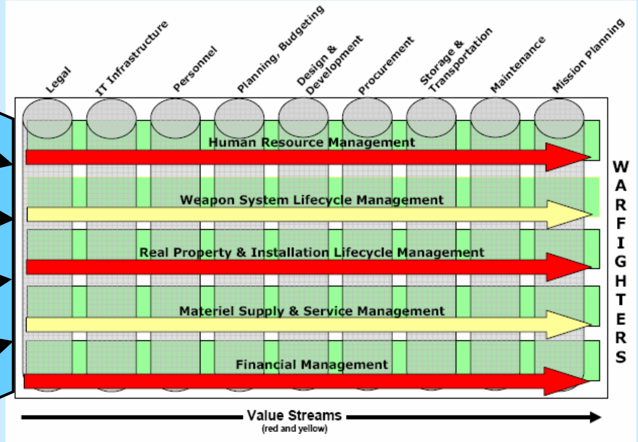


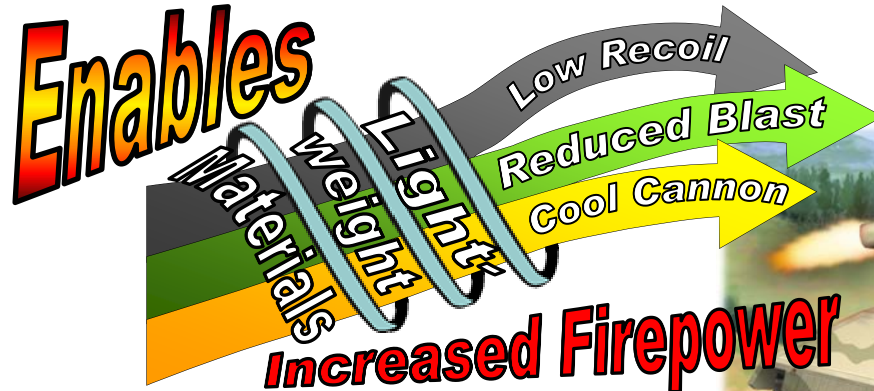
U.S. Army Research, Development and Engineering Command
Benét Laboratories

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

RAREFACTION WAVE GUN
TANK MAIN ARMAMENT DEMONSTRATOR

Presented by: David C. Smith, P.E.
Written by: Eric Kathe, Ph.D., P.E.
Benét Laboratories, Watervliet Arsenal, NY

RAVEN RArefaction waVE guN



RAVEN is a hybrid propulsion that achieves:

The ballistic efficiency of orthodox guns.

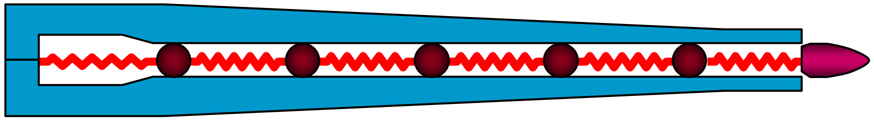
The recoil advantage of prior recoilless rifles.

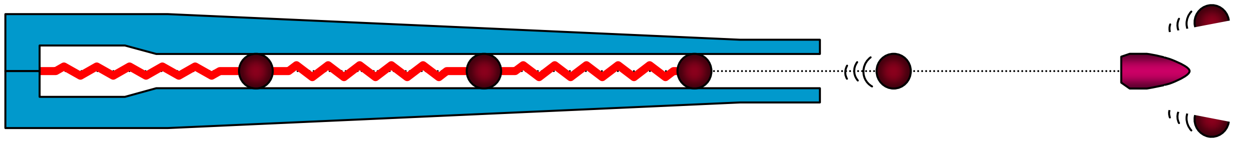
Unprecedented reductions in barrel heating.

Increased accuracy.

- For an orthodox gun, recoil is imparted by both the projectile and propellant.
  - Envision propellant as n “billiard balls” pressurized by massless springs. (This is a “Finite Volume” approximation.)
  - Each “billiard ball” has a mass, mci, equal to the total charge mass divided by n.
  - After shot exit, the propellant gases continue to expand and accelerate out of the cannon.

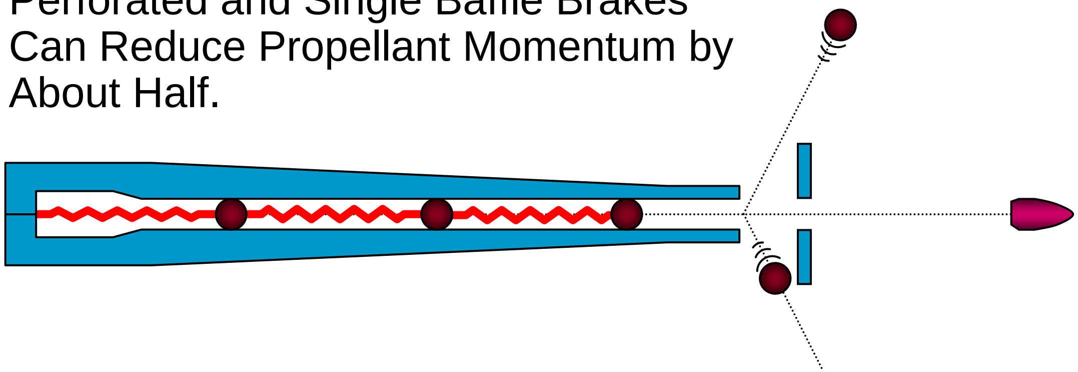
- For tank gun KE rounds, there is more recoil from the propellant gas than the bullet.



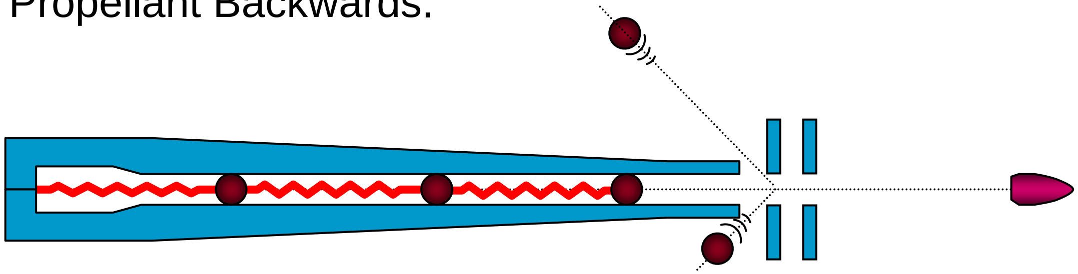


- Muzzle brakes reduce momentum by redirecting muzzle blast sideways or aft.

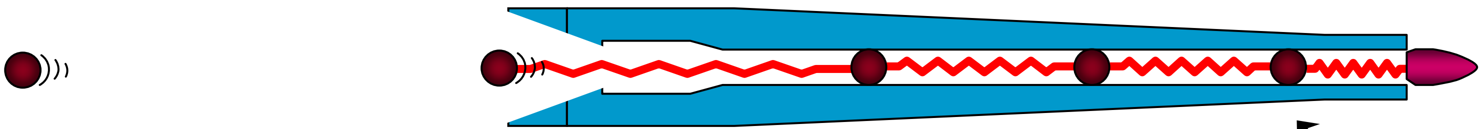
Perforated and Single Baffle Brakes Can Reduce Propellant Momentum by About Half.



Double Baffle Brakes Can Deflect Propellant Backwards.



- RAVEN sends propellant backwards before projectile exit.
  - A delay time occurs between “uncorking” the breech and the forward propagation of the pressure loss through the propellant gas column.



Rarefaction Wave Front

  - Between the base of the projectile and here, the conditions are the same as for closed breech firing.
  - Pressure, density, and temperature are reduced behind the wave front.

- Heat transfer to the bore of a gun is estimated as (AMCP 706-150 page 3-2):

$$q(x) = \int_0^{t_f} \frac{1}{2}\lambda(x)\left(\frac{\gamma R}{\gamma - 1}\right)\rho(x,t)v(x,t)\left(T_g(x,t) - T_w(x,t)\right)dt$$

- Using representative average values and considering the wall temperature to be small, net heat transfer is essentially proportional to:
  - gas density,
  - gas velocity,
  - gas temperature, and
  - duration of exposure.

$$q(x) \propto \overline{\rho}(x,t)\overline{v}(x,t)\overline{T}_g(x,t)\Delta t$$

- RAVEN Reduces:
  - gas density,
  - gas velocity,
  - gas temperature, and
  - blow-down duration.

- Gun barrel erosion commences in earnest only after reaching the Arrhenius threshold temperature of 1007K for gun steel.
  - Below this temperature, gun steel does not react with propellant gas
  - Above this temperature, gun steel "burns†."
  - RAVEN reduces or eliminates exposure duration above the Arrhenius threshold.

† Chemical reactions with propellant that release heat

- Following the successful trials in 35mm, a large caliber RAVEN was developed using design and hardware assets remaining from the 105mm Multi-Role Armament and Ammunition System (MRAAS) program.

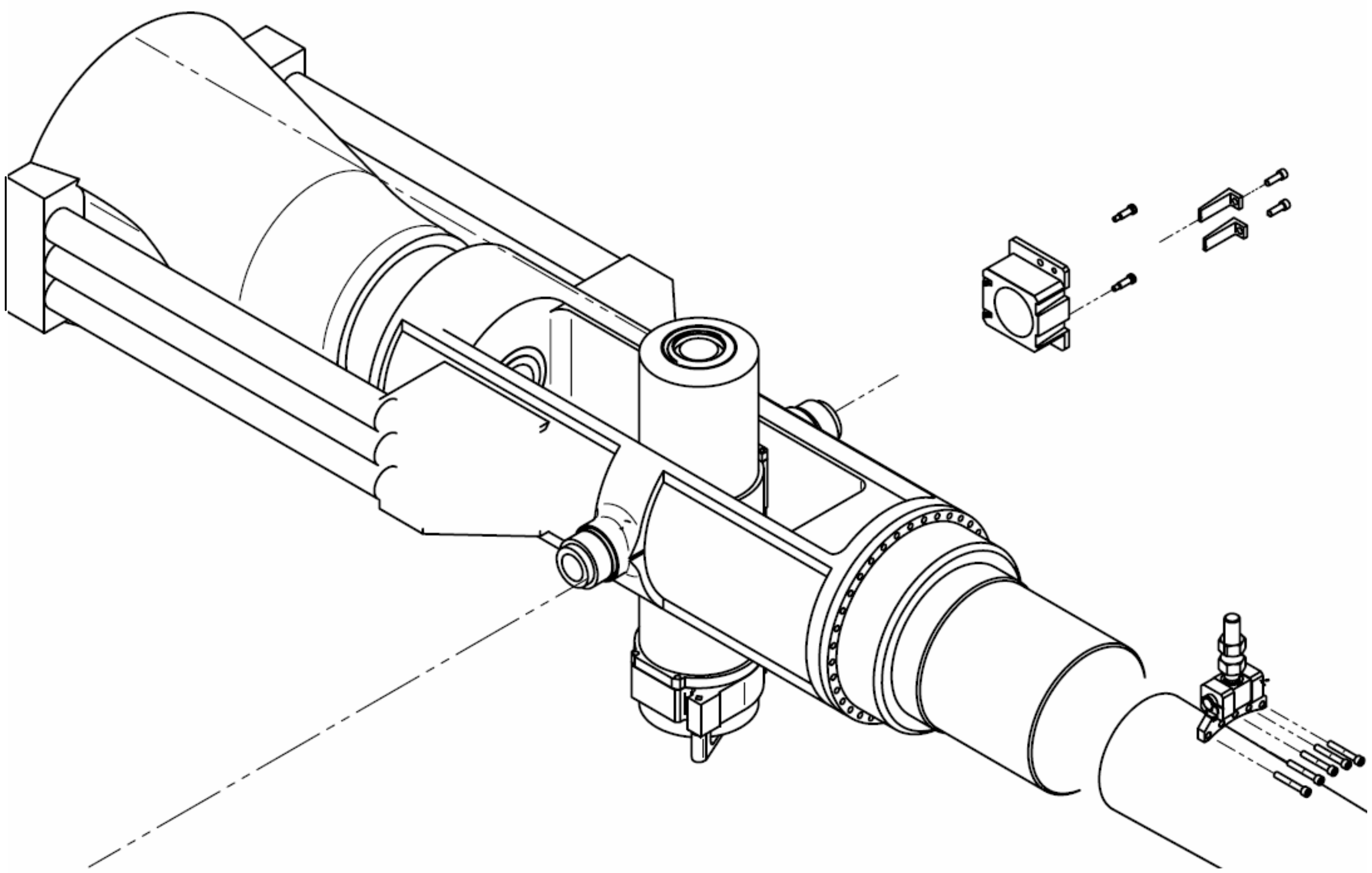
MRAAS incorporated a novel swing chamber.
It was engineered to provide 120mm tank gun lethality from a 105mm bore, and . . .
..to fire beyond line of sight (BLOS) and non line of sight (NLOS) missions.

LOS Demonstration

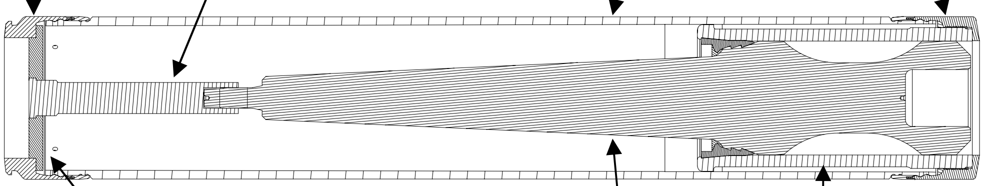
BLOS/NLOS Demonstration

MRAAS Firing Video Showing Load and Fire

- MRAAS rotating chamber gun shown open with integrated blow-back nozzle/bolt.

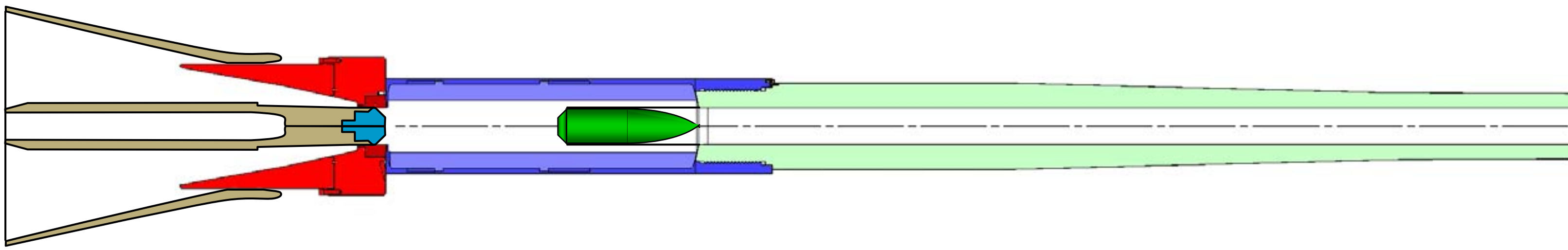


- Employs a balanced blow-back bolt with integral expansion nozzle and hydro-pneumatic recoil cylinders.
- The recoilless barrel will substantially reduce muzzle whip, and, thus, increase accuracy.



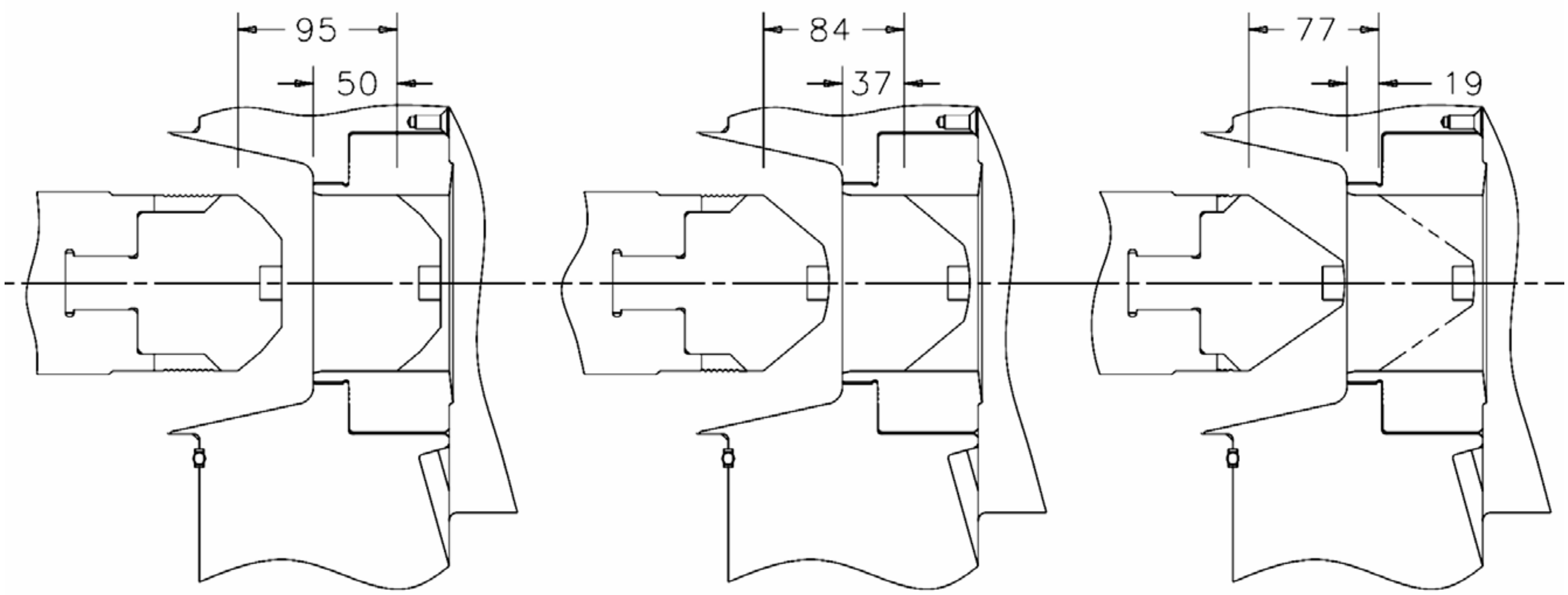
The swing chamber approach affords a straightforward munitions handling method to accommodate RAVEN's rearward facing expansion nozzle.

105mm Operating Principle



- Intentional rupture of cartridge case.
  - Compatible with modular artillery charge and modified cartridge case technology.
- Breech travel governed by same propellant pressure that drives the projectile.
- Recoil stroke to vent port and recoil mass determine vent time.
- Robust, reliable, and weaponizable . . .
  - Prior 35mm tests verified 1% standard deviation in occasion to occasion blow-back bolt vent timing.

Variation in Vent Timing



- Vent timing hastened by progressively increasing sharpness of bolt faces from blunt nosed to conical.
  - Recoil stroke to commence venting varies from 19mm to 50mm as shown above.
  - The upper displacement approximates recoil stroke to un-choked flow.

105mm Results

Shot 3 Experimental Results.

m_p	8.31	Kg
m_c	6.29	Kg
v_m	1.16	km/s
I_p	9.6	kN*s
I_T	12.4	kN*s

			1	2	3	4	5	6		17
Shot number			1	2	3	4	5	6		17
Date			2/19	4/14	5/1	5/19	8/13	8/27		TBD
Test Set-up	Distance to Vent	mm	50	42	42	50	43	37		Closed
	Projectile Mass	Kg	8.31	8.31	8.31	8.31	8.31	8.31		8.31
	Charge Mass	Kg	4.97	5.65	6.29	6.78	6.75	7.05		6.98
	Chamber Volume	L	7.71	7.71	7.71	7.71	7.78	7.84		-
Predicted Results	Muzzle Velocity	km/s	1.12	1.26	1.40	1.50	1.49	1.55		1.57
	Max Pressure	MPa	217	306	454	563	551	643		669
	Momentum	kN*s	9.6	10.7	12.6	14.7	14.0	14.4		24.2
Experimental Results	Muzzle Velocity	km/s	-	-	1.16	1.34	1.37	1.38		-
	Max Pressure	MPa	167	225	-	389	-	447		-
	Momentum	kN*s	-	-	12.4	12.9	12.7	-		-

- **Reduce Recoil Severity Imposed on Combat Vehicles.**
  - **Facilitates large-gun / small-vehicle integration.**
  - **Eases burdens of fire on the move integration.**
- **Increased Thermal Performance.**
  - **Enables use of hotter propellants to achieve higher velocities.**
  - **Nearly doubles sustained firing rate.**
  - **Nearly doubles number of burst fire rounds.**
- **Enables lightweight cannon.**
  - **Recoil energy is inversely proportional to recoil mass.**
  - **Burst fire thermal capacity is proportional to thermal mass.**
  - **Facilitates large-gun / small-vehicle integration.**
- **Reduces and redirects blast.**
  - **Will enable “hatches open” operation while meeting requirements of MIL-STD 1474D.**

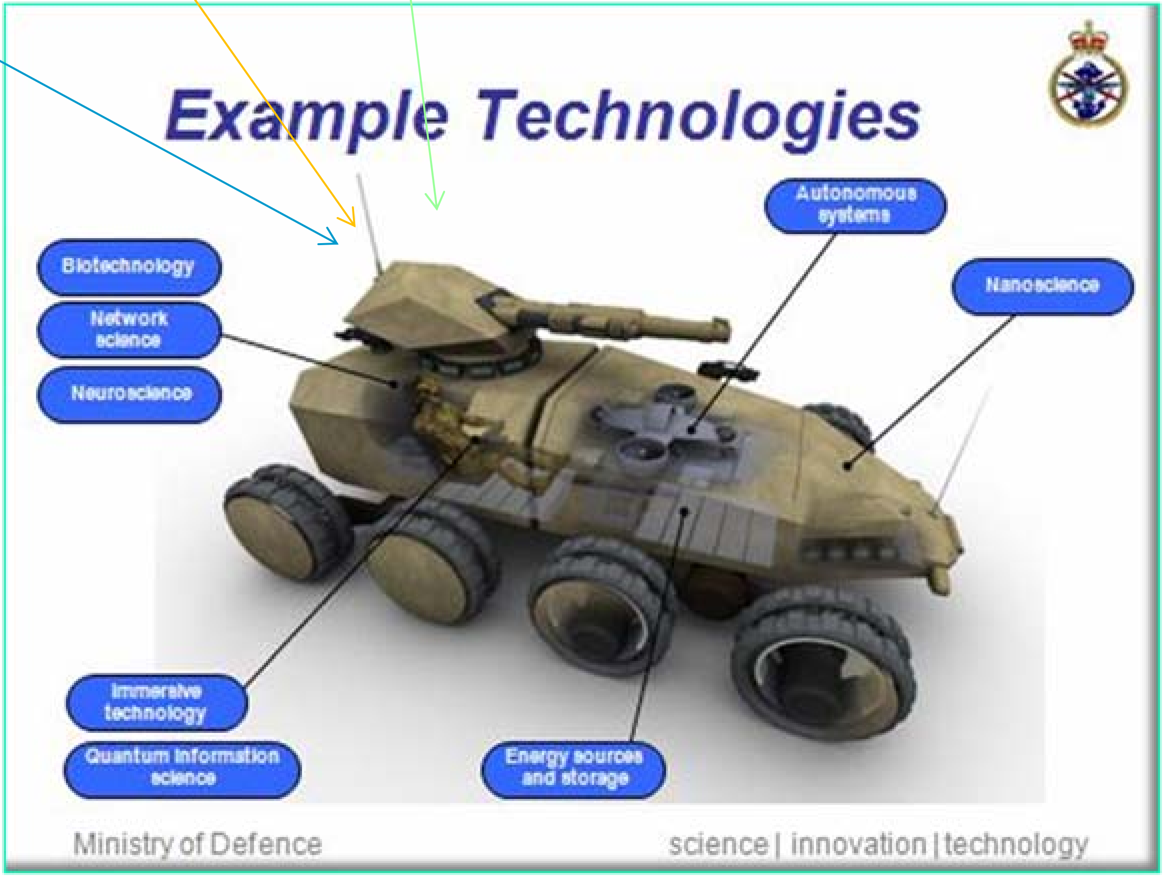
XM360 LOS/BLOS

XM324 NLOS-C

XM325 NLOS-M

RAVEN

RAILGUN



Concept Vehicle courtesty of:
Professor Phil Sutton, Director General Science &Technology Strategy, UK MOD

- A truly large caliber rarefaction wave gun has been designed, fabricated, and is currently undergoing test and validation.
  - Results from this brassboard demonstrator support the fundamental precept of RAVEN that venting a large caliber gun during the ballistic cycle does not slow the bullet.
- RAVEN has been successfully integrated with a novel swing-chamber munitions handling interface.
  - This interface affords straightforward combat system integration of this armament technology.

BAE SYSTEMS

155 Third Generation Maritime Fire Support (155 TMF)

Robert McClure

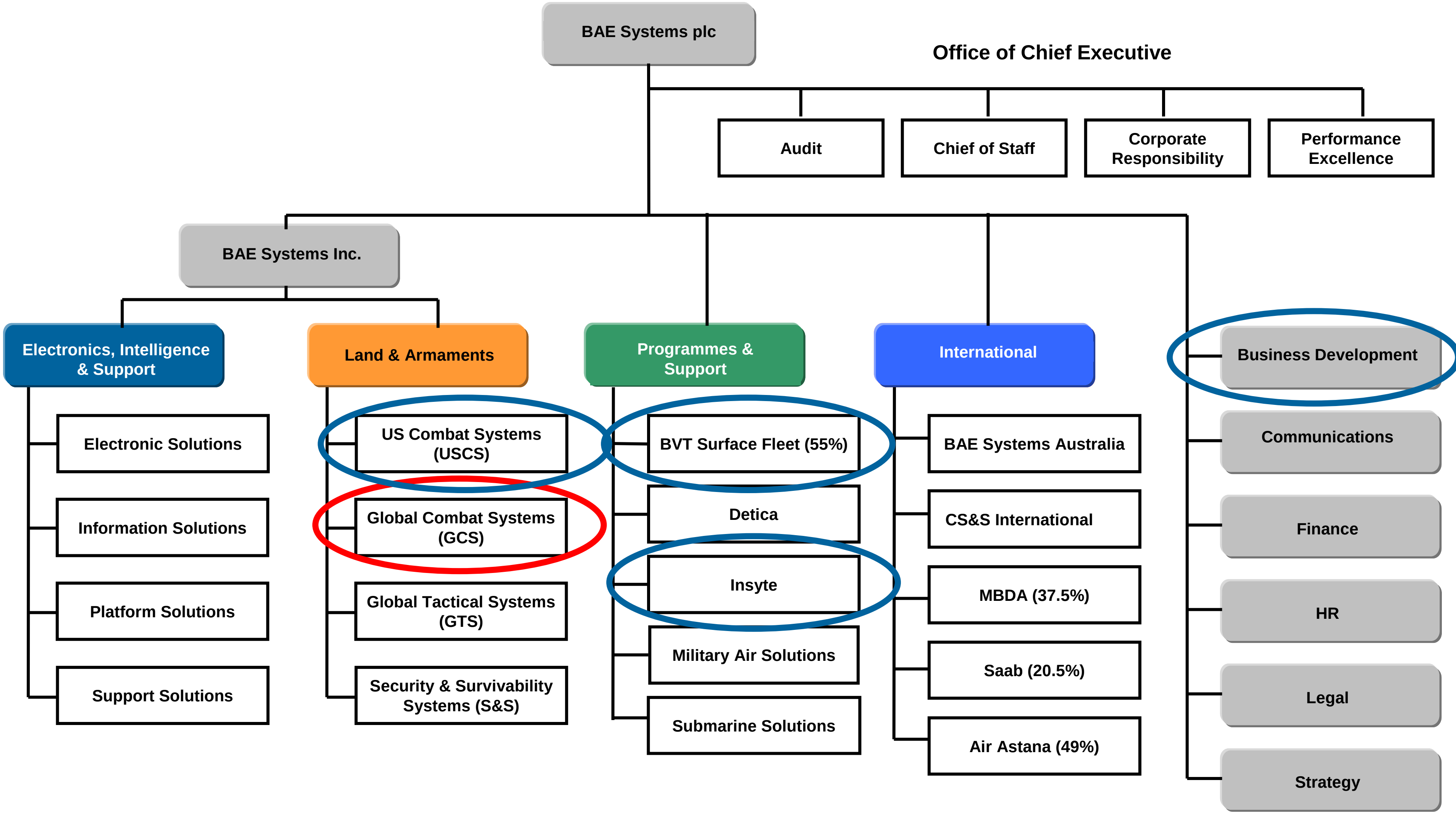
BAE Systems Global Combat Systems

Unrestricted

Contents

- BAE Systems Context
- Global Combat Systems Products
  - AS90 Self Propelled
  - Mk8 4.5” Naval Gun
- Maritime Fires Capability Requirement
- 155mm Third Generation Maritime Fire Support (TMF)
- Summary & Questions

BAE Systems Context



BAE SYSTEMS

155mm Third Generation Maritime Fire Support (TMF)



AS90 Self Propelled Howitzer

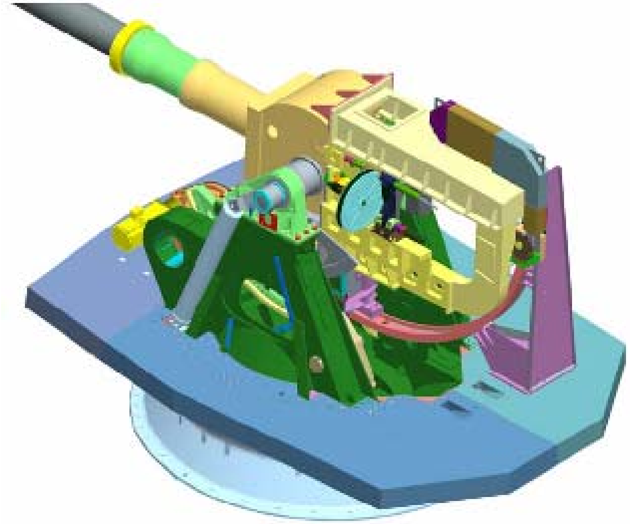
- Entered service in 1993 following competitive tender
- 179 vehicles over six UK regiments
- JBMoU 39 cal 155mm ordnance
  - Two piece ammunition
  - 24.7km range
  - HE, Illum, Smoke
  - Precision Guided Munitions capability
- Operational service in Op Telic
  - NAO reported 95% availability
- Contract to ‘up-gun’ to 52 cal barrel in 2002
  - Cancelled due to failure of modular charge system to meet requirements
  - Design experience and trials data pull-through

Mk8 4.5" Naval Gun

- Designed by RARDE – built by BAE Systems
  - First prototype 1966
  - Entered service (Iran) 1971
  - UK Service 1973 HMS Bristol
- UK Royal Navy standard Medium Calibre Gun
  - Type 21, 22, 23 frigates
  - Type 42, Type 45 destroyers
- In service in Brazil, Chile, Pakistan
- 4.5" one piece ammunition
  - Range 22km
  - 21kg shell
  - Base-bleed extended range
- BAE contacted in 1998 to develop mod 1 upgrade
  - Addresses obsolescence, reliability and maintainability
  - Tranche 1 completed by BAE Systems
  - Tranche 2 ongoing by DML

155 TMF Concept Objectives

- Affordable route to provide a significant increase in Naval Gun capability
  - Retain 4.5” Mk8 Mod 1 mount structures and high value components
  - Adapt AS90 ordnance
  - Modify for environment
- UK research driven by FSC
- Additional opportunities



Maritime Fires Capability Requirement

- Factors
  - Future Surface Combatant to replace Type 23/22
  - Enduring need for Naval gun capability identified
  - Capability requirements evolving: effect, range, rate of fire
  - Objective to reduce whole life cost
  - 155TMF key programme for industrial capability
- FSC Options
  - No gun
  - Use existing gun: Mk8 4.5” - 114mm
  - Buy new
  - Upgrade: 155mm TMF
- So What?
  - UK Research programme mitigating technology risk
  - BAE Systems strategy based on 155mm TMF

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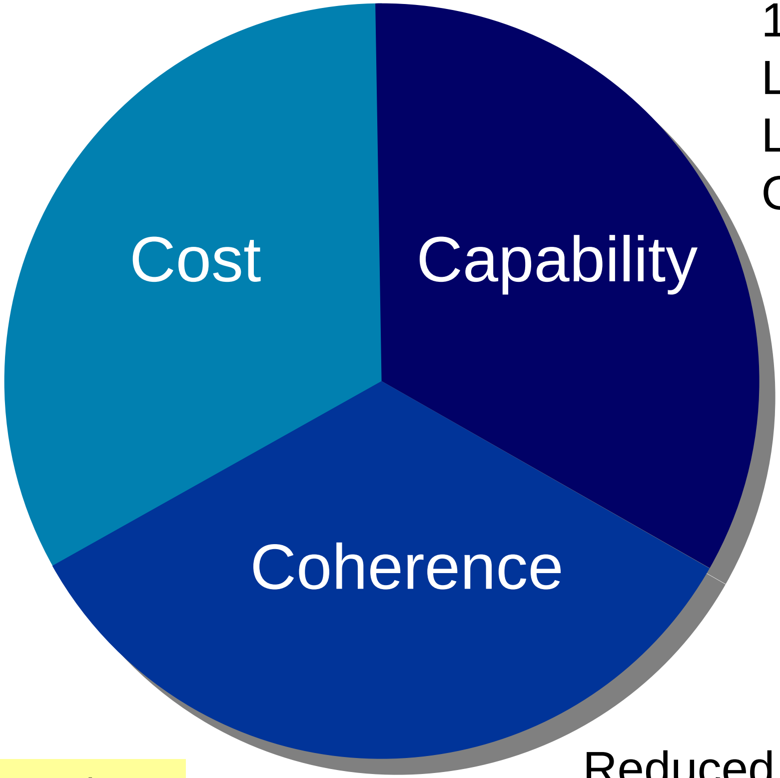
TMF Key Attributes

Commonality with Mk8 drives low acquisition cost
Commonality with AS90 reduces development cost
Projectile commonality drives lower through-life cost

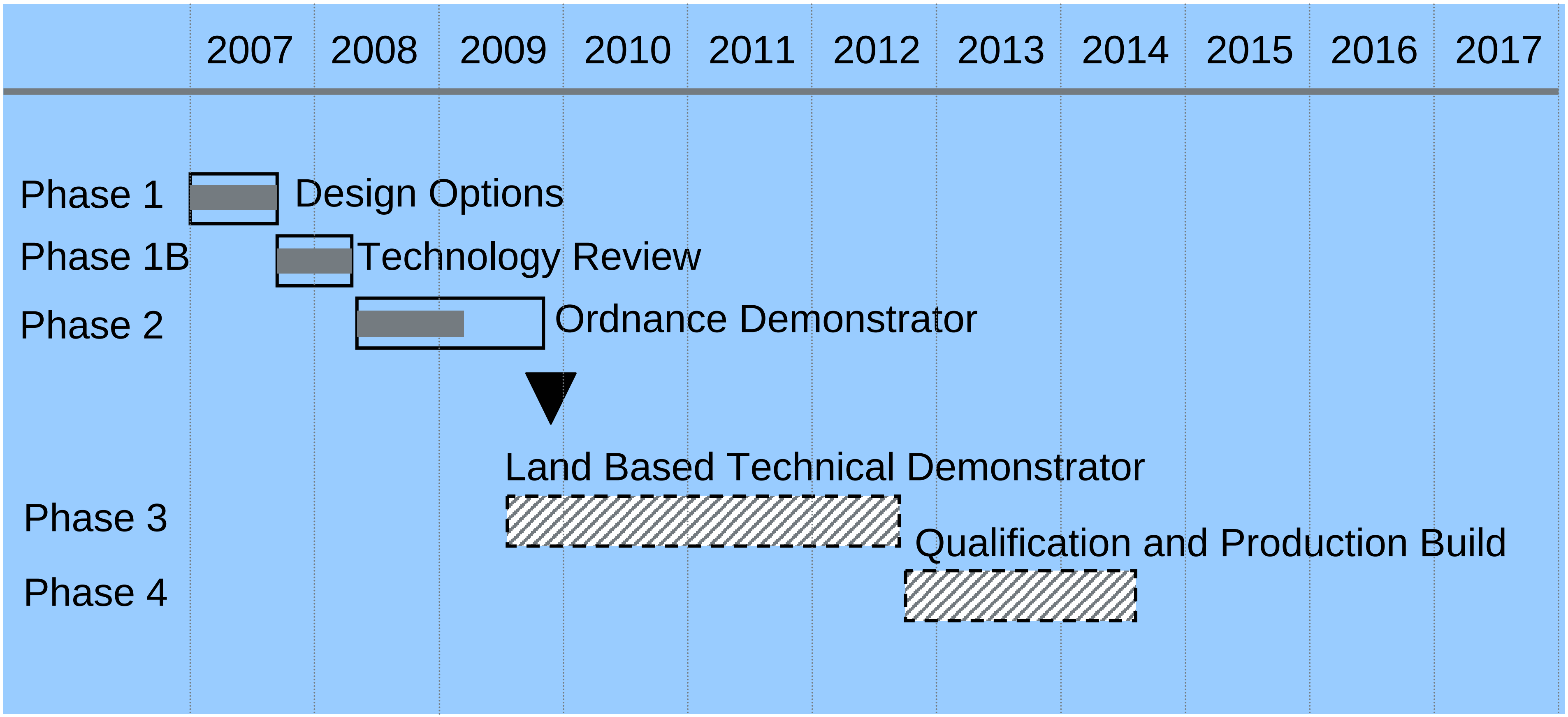


155mm target effect
Long range
Light weight
Growth potential

Reduced logistics burden
Exploit land investment
Joint development opportunities

Provides an affordable enhancement in capability with low through-life costs. Commonality enables a coherent strategy for land and naval fires

155TMF Current Programme



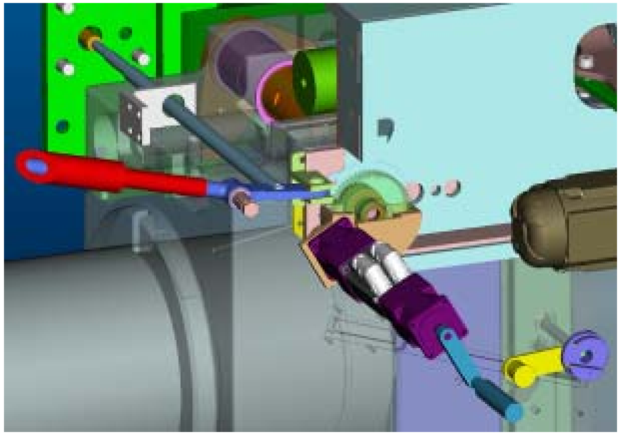
Contract through the UK MoD Defence Technology and Innovation Centre
Main stakeholder: Director of Equipment Capability (Above Water Effects)

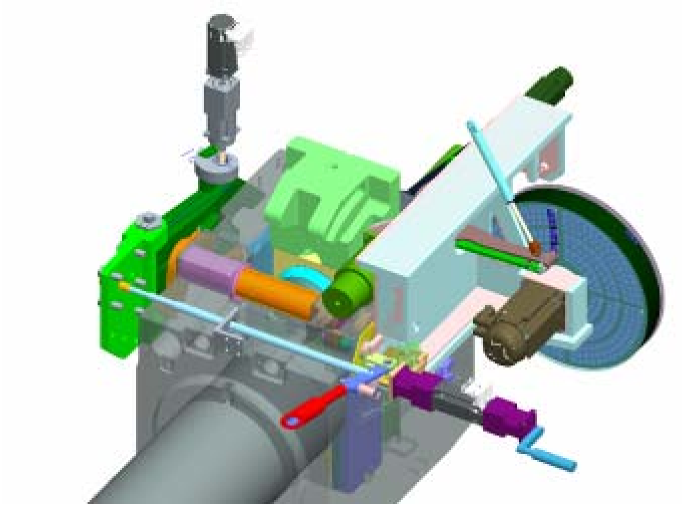
155mm Naval - Future Coastal Suppression Study

- 155mm Weapon System
- Ammunition Handling
- Retained Structures
- Ship Installation
- Risk Reduction Prototype

155mm Naval - Future Coastal Suppression Study

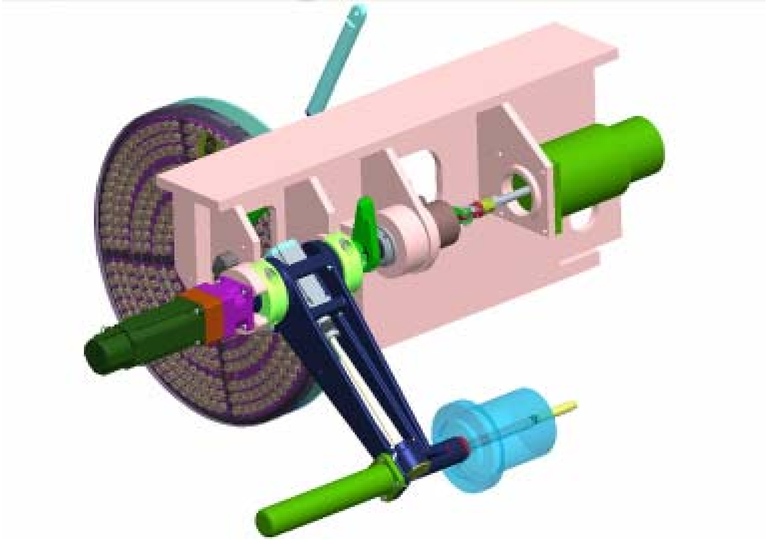
- 155mm WEAPON SYSTEM
  - Ordnance Automation

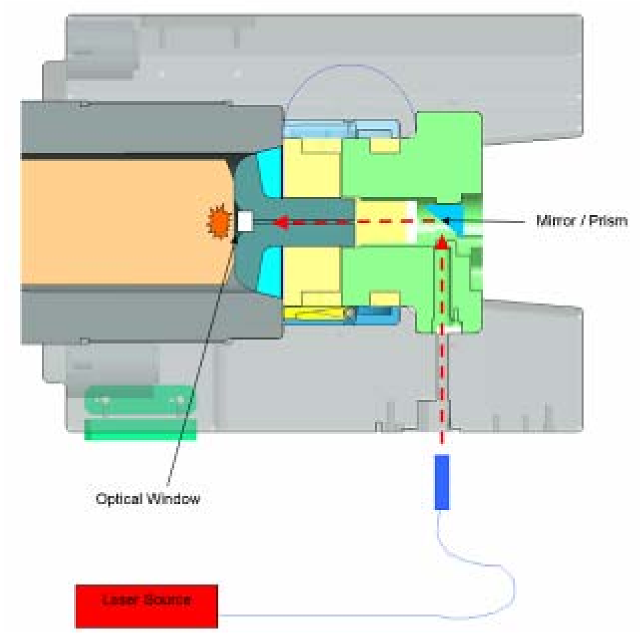


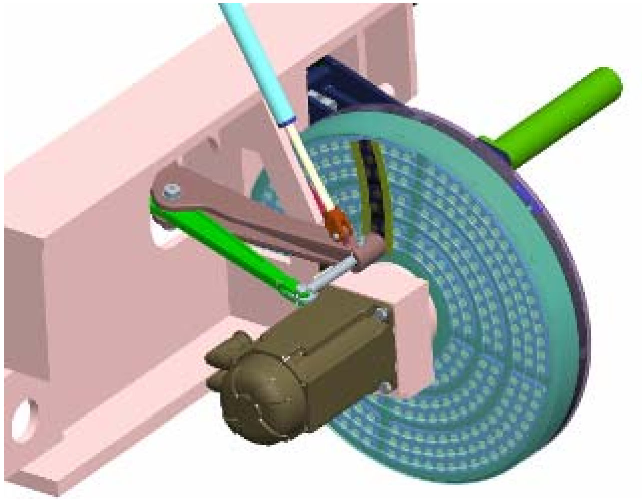


155mm Naval - Future Coastal Suppression Study

- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition

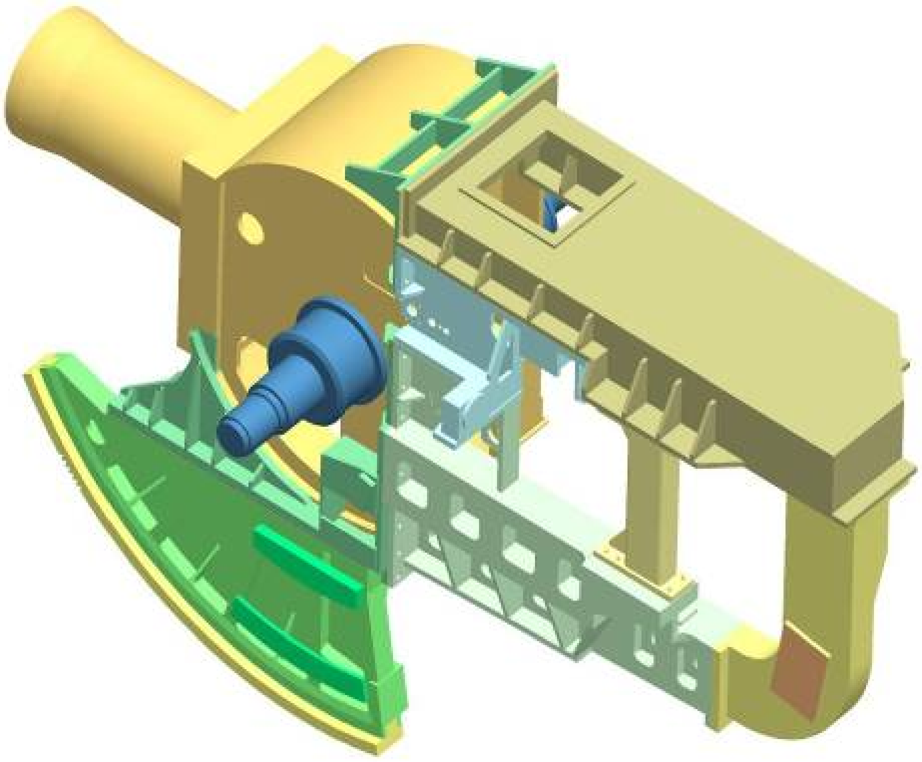






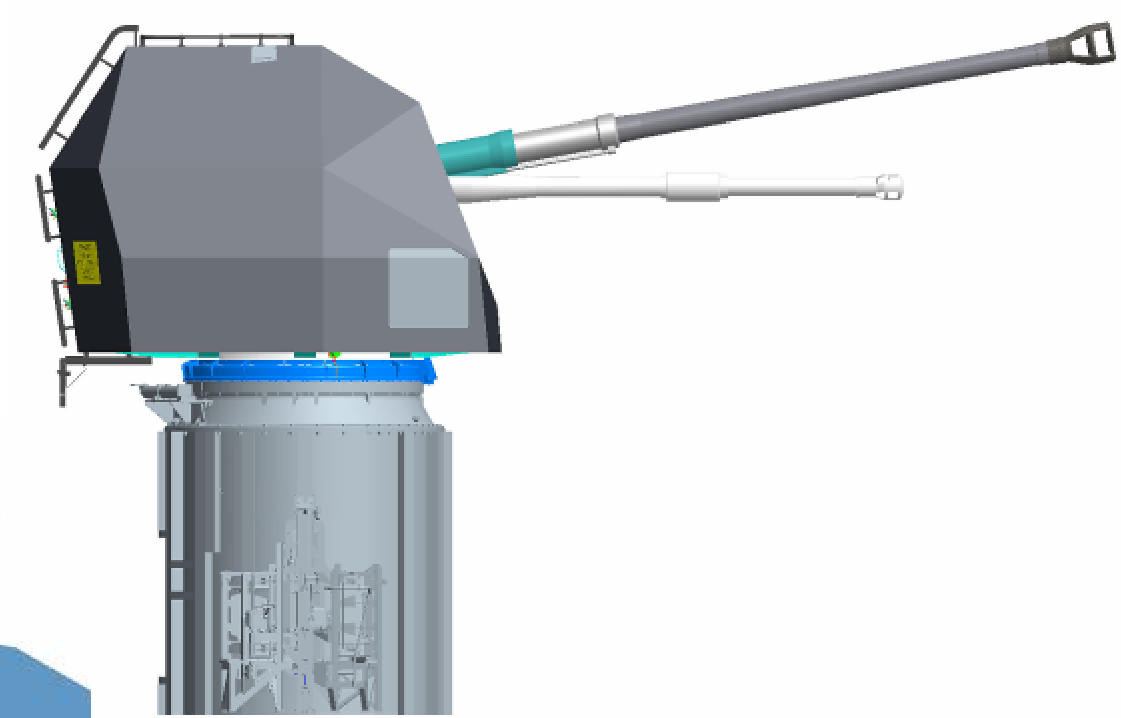
155mm Naval - Future Coastal Suppression Study

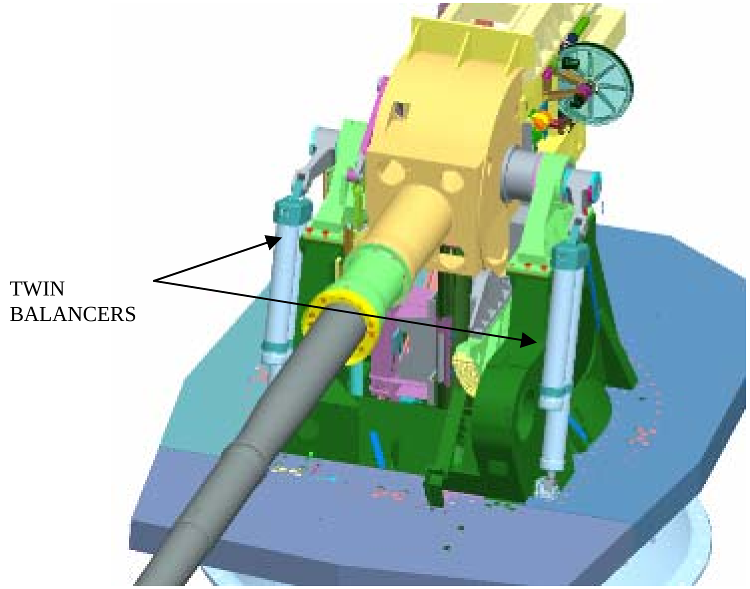
- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition
  - Cradle Design



155mm Naval - Future Coastal Suppression Study

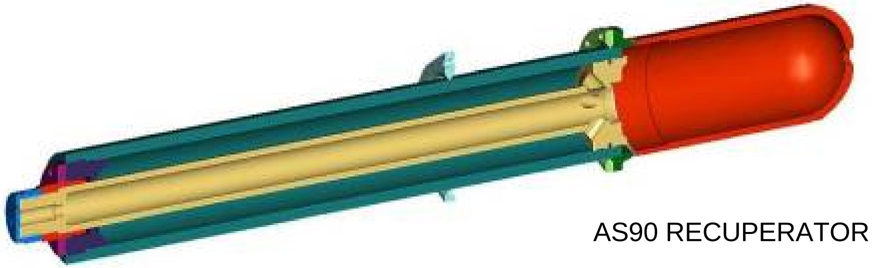
- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition
  - Cradle Design
  - Balance System

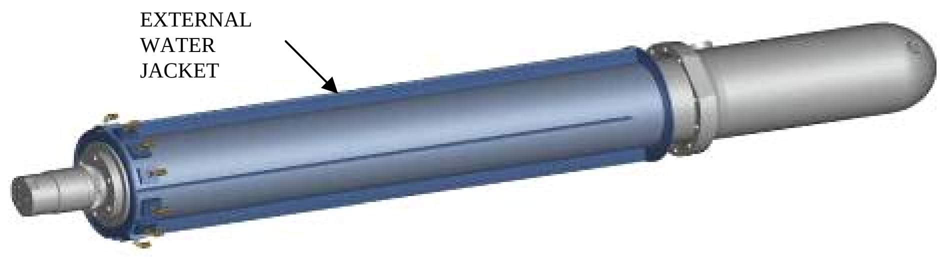




155mm Naval - Future Coastal Suppression Study

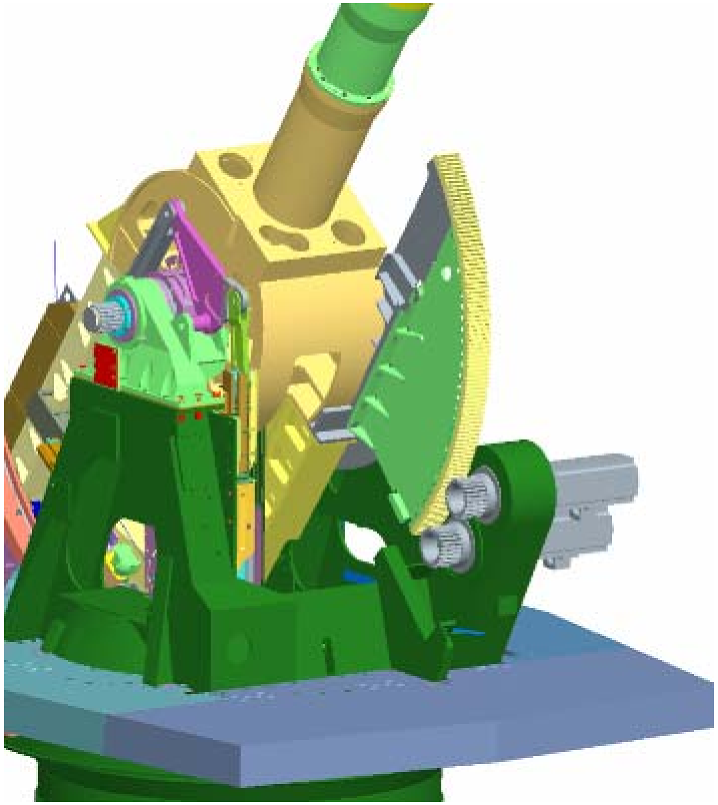
- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition
  - Cradle Design
  - Balance System
  - Recoil System





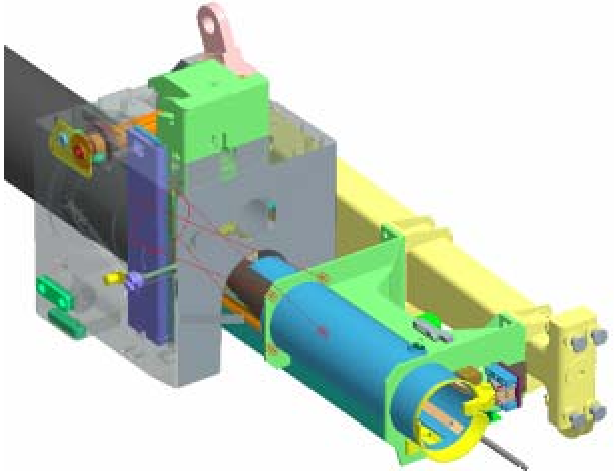
155mm Naval - Future Coastal Suppression Study

- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition
  - Cradle Design
  - Balance System
  - Recoil System
  - Elevation & Training Drives

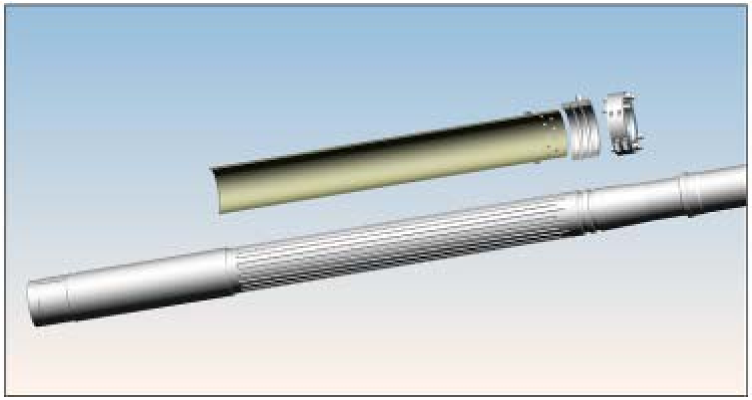


155mm Naval - Future Coastal Suppression Study

- 155mm Weapon System
  - Ordnance Automation
  - Charge Ignition
  - Cradle Design
  - Balance System
  - Recoil System
  - Elevation & Training Drives
  - Thermal Management



Pulse Bore Spray Arrangement



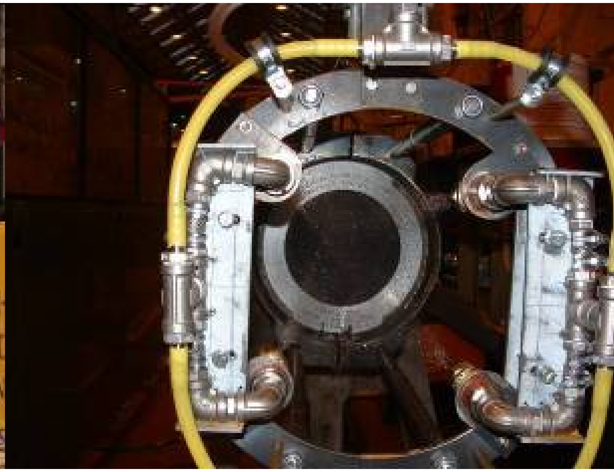
Grooved Barrel with Cooling Sleeve

BAE SYSTEMS

Barrel Thermal Management

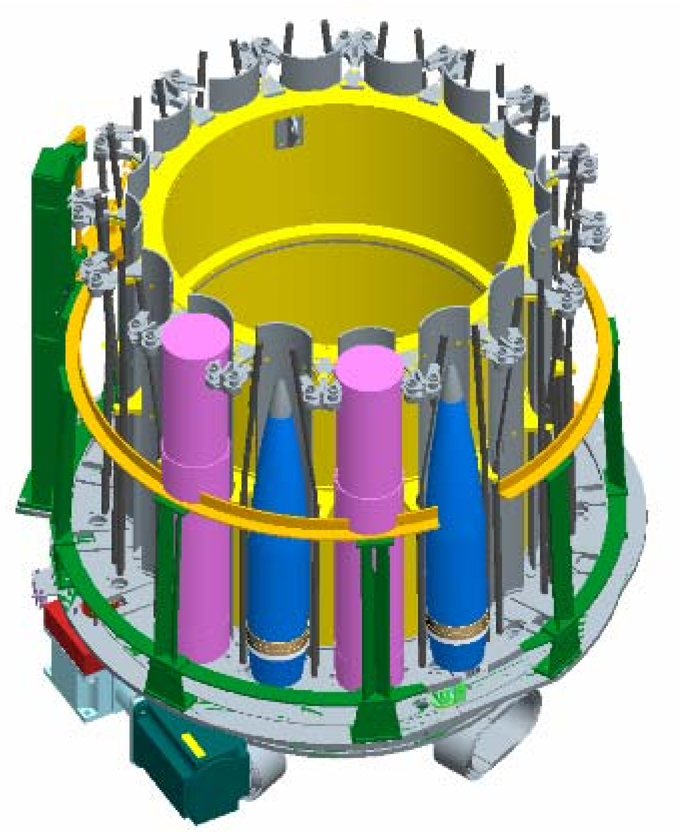




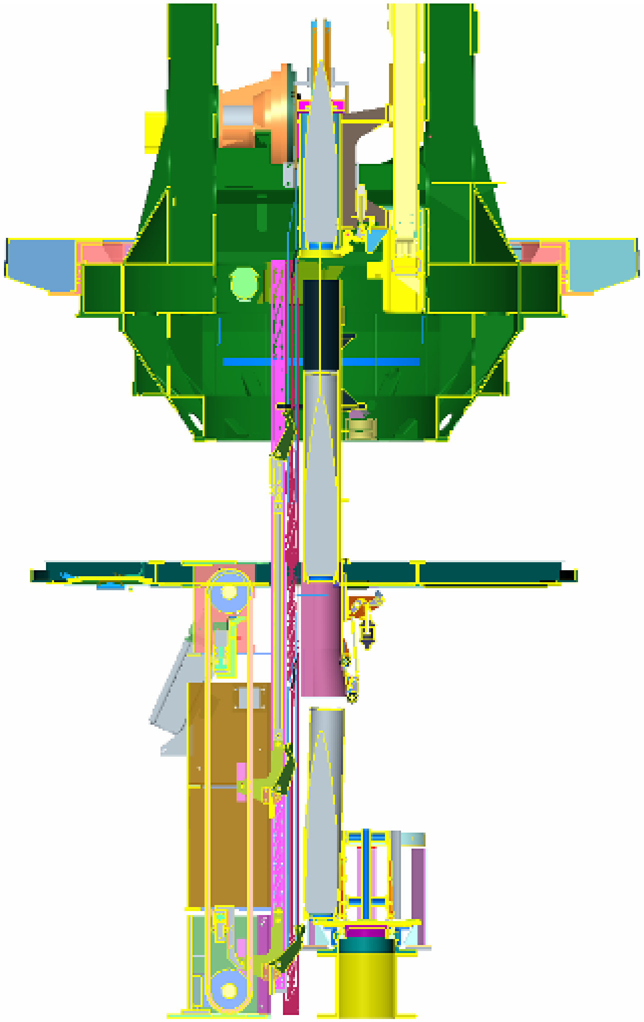
155mm Naval - Future Coastal Suppression Study

- Ammunition Handling
  - Feedring



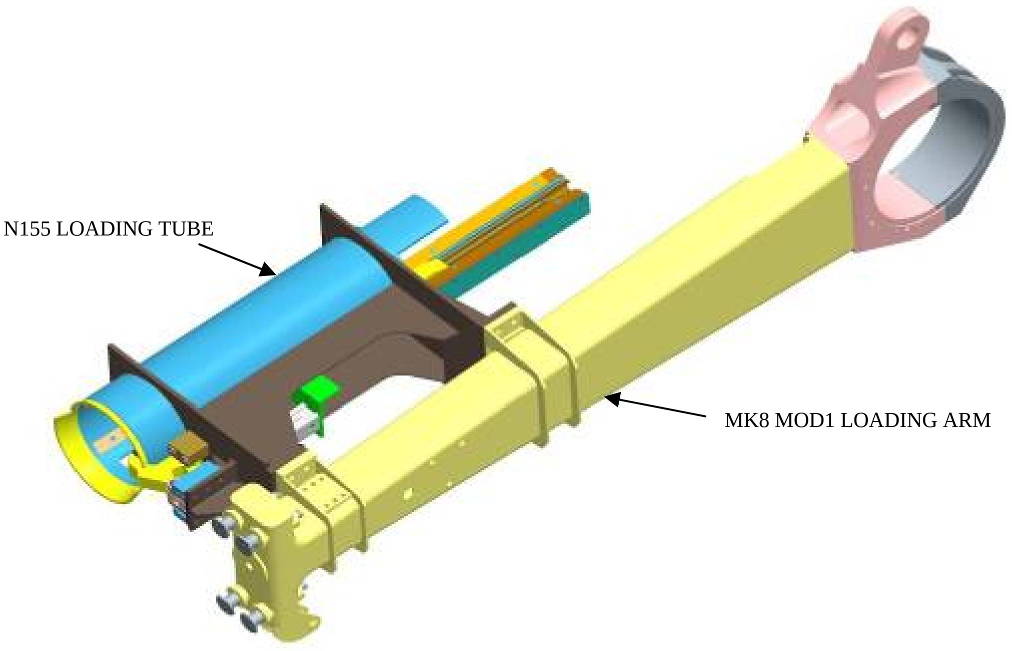
155mm Naval - Future Coastal Suppression Study

- Ammunition Handling
  - Feedring
  - Hoist



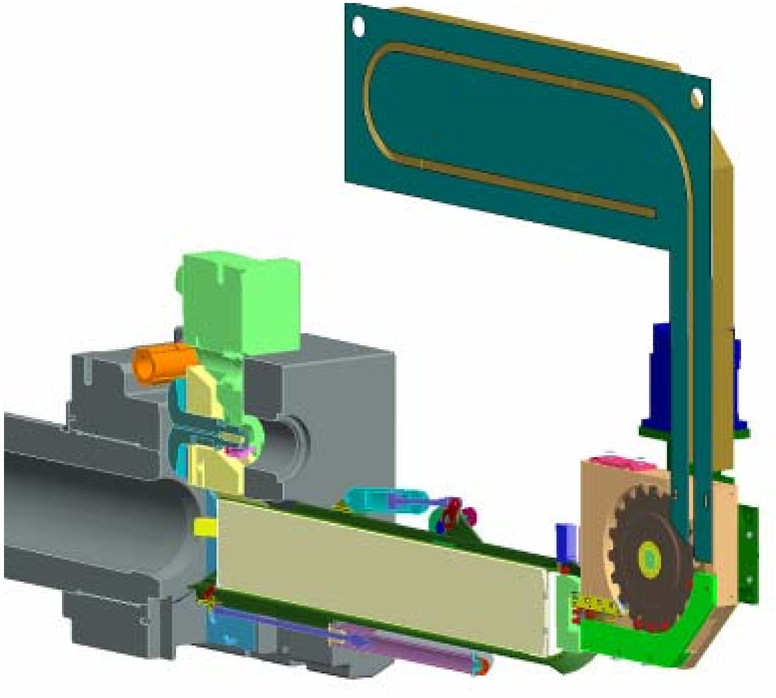
155mm Naval - Future Coastal Suppression Study

- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm



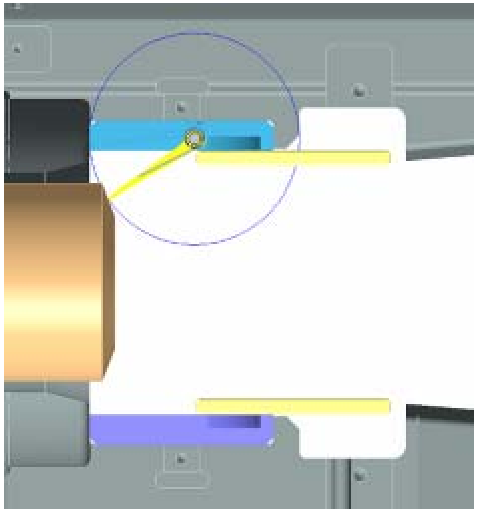
155mm Naval - Future Coastal Suppression Study

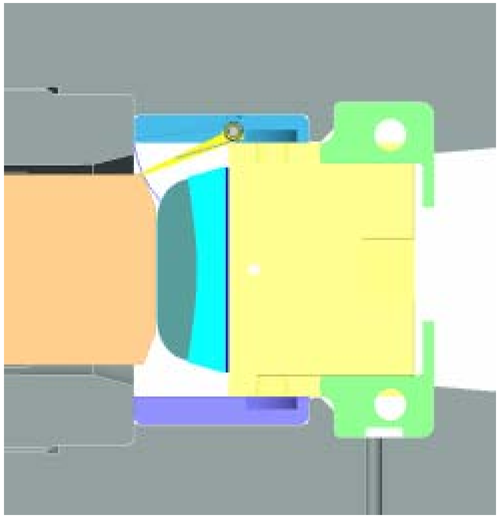
- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm
  - Rammer System

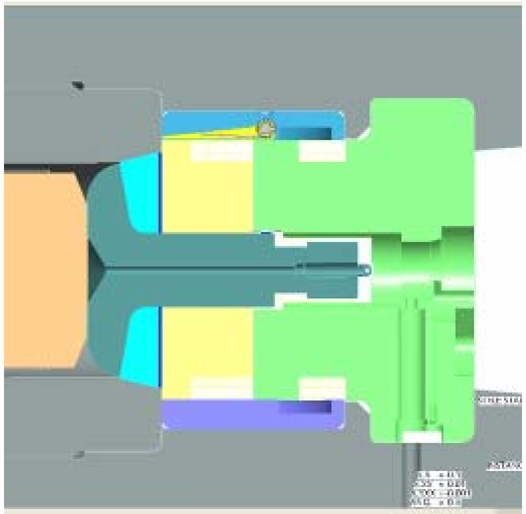


155mm Naval - Future Coastal Suppression Study

- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm
  - Rammer System
  - Charge Retention



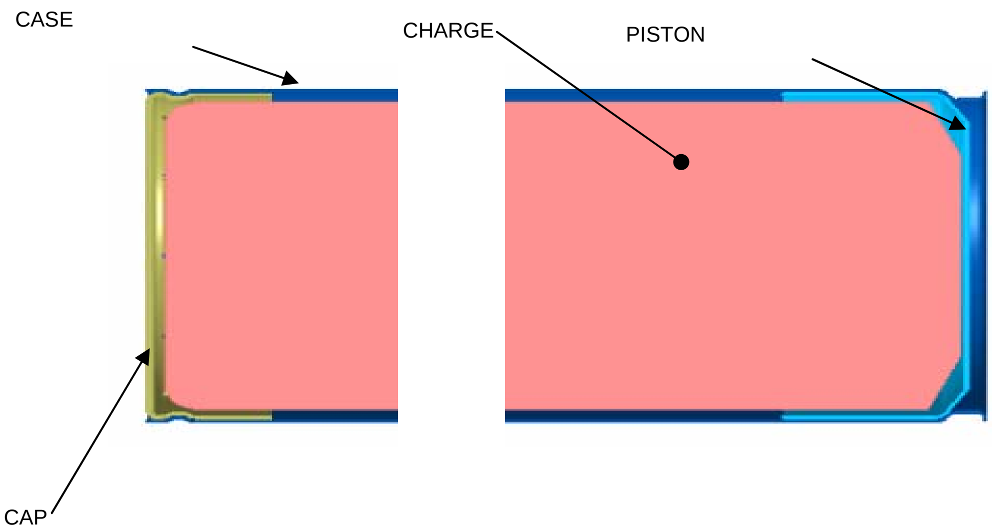




155mm Naval - Future Coastal Suppression Study

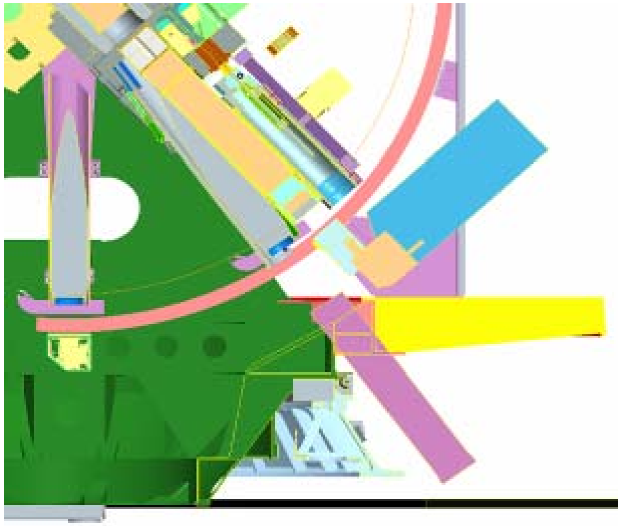
- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm
  - Rammer System
  - Charge Retention
  - Charge Protection Case

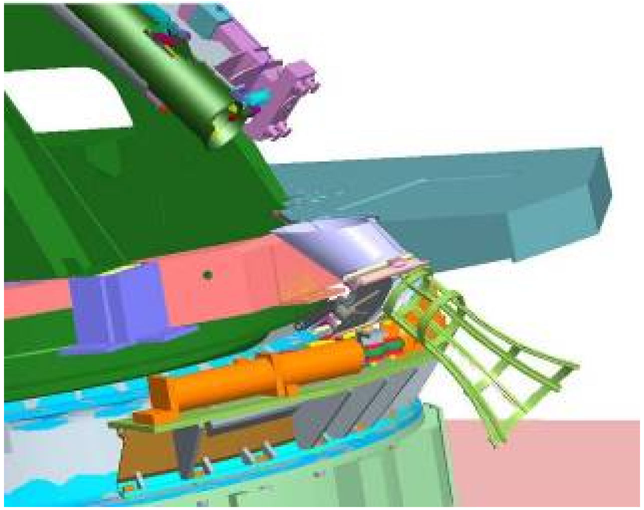
PROTOTYPE CPC ASSEMBLY



155mm Naval - Future Coastal Suppression Study

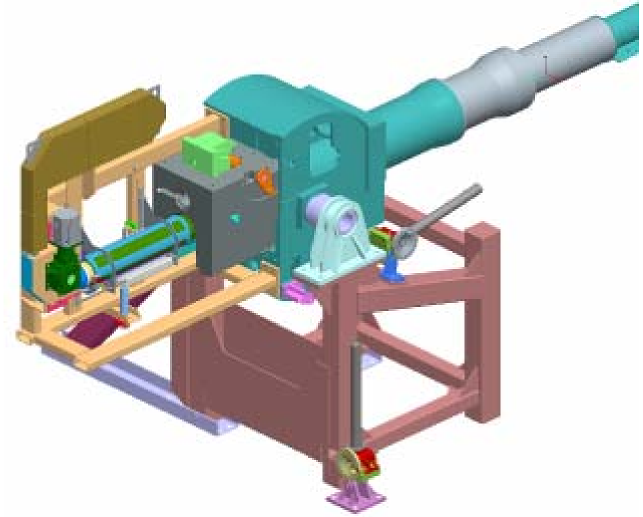
- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm
  - Rammer System
  - Charge Retention
  - Charge Protection Case
  - CPC Ejection





155mm Naval - Future Coastal Suppression Study

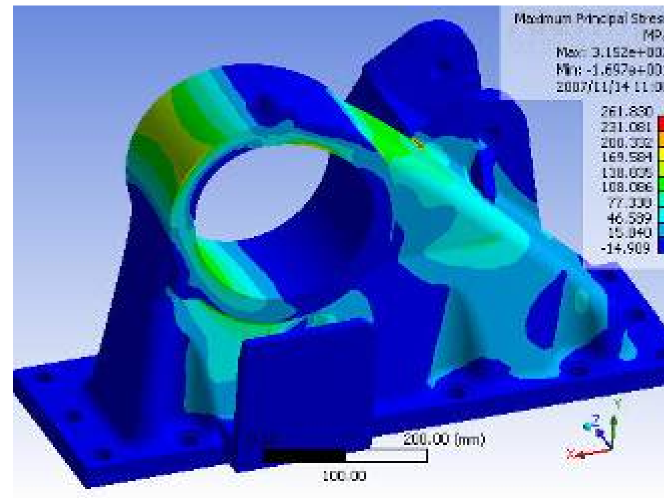
- Ammunition Handling
  - Feedring
  - Hoist
  - Loading Arm
  - Rammer System
  - Charge Retention
  - Charge Protection Case
  - CPC Ejection
  - Rammer Test Rig

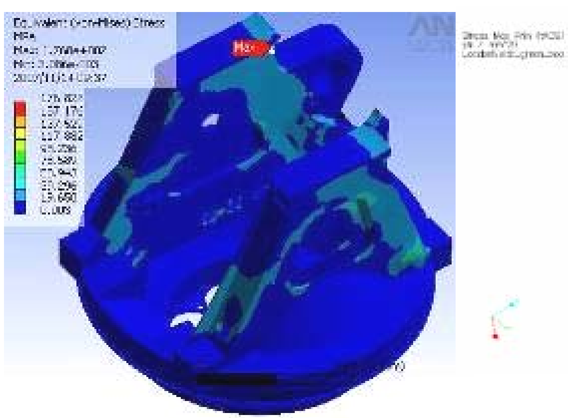


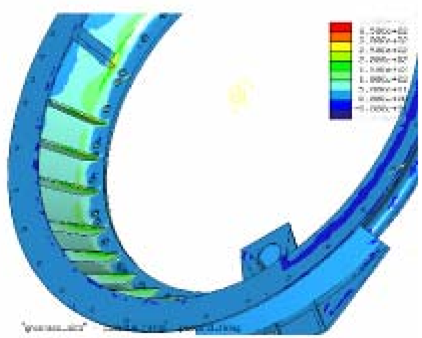

155mm Naval Gun
Rammer Test Rig

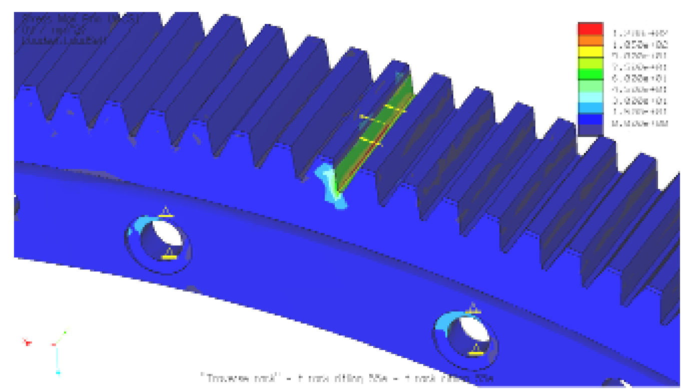
155mm Naval - Future Coastal Suppression Study

- Retained Structures
  - Turntable And Carriage
  - Training Bearing
  - Training Drive Arc
  - Elevation Drive Arc
  - Pedestal Base
  - Gun House Floor









155mm Naval - Future Coastal Suppression Study

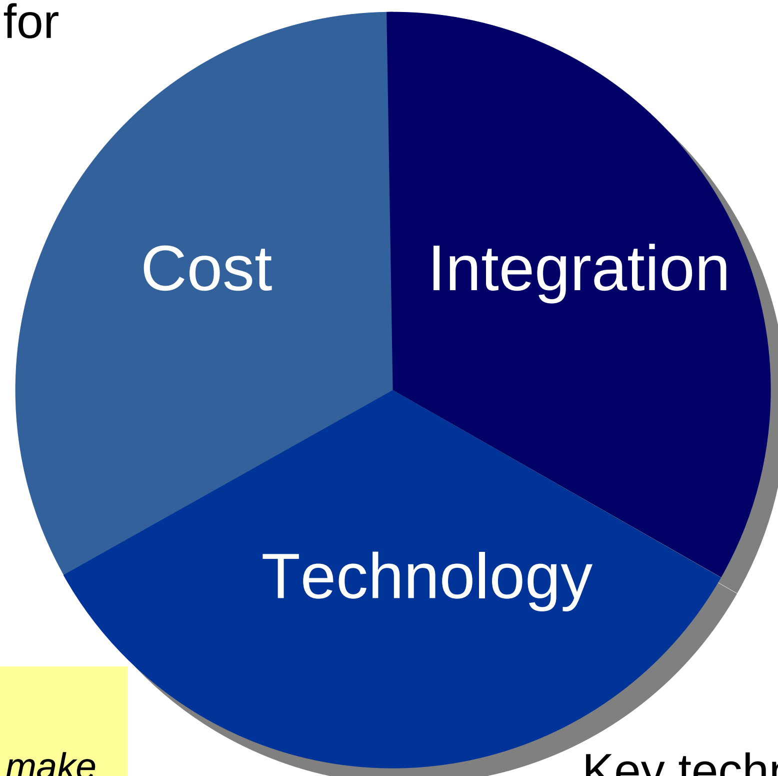
- Ship Installation
  - Type 23 Ship Structural Interfaces
    - Minor reinforcement
  - Type 45 Ship Structural Interfaces
    - Minor reinforcement and minor structural stiffening
  - Electrical System Modifications
    - Additional control and drive systems defined and power requirements estimated
    - Harmonic limits for ships supply met
  - Fire Control Interfaces
    - Ballistic calculations can be updated
    - Capacity available to control future intelligent munitions
    - Existing system interfaces will allow integration with wider battlefield command and control systems

BAE SYSTEMS

Key Success Factors

Need to demonstrate value for money vs. “do nothing” option (Mk 8 4.5”)

- Development and Qual
- UPC
- Integration Cost
- Through Life Support



Key integration aspects

- Ship Installation
- Fire Control
- Ammunition Stowage and Handling
- Land / Maritime Coherence

Wider Strategic Aims

- *Support Home Market strategy: make wider BAE expertise available to the customer through UK business unit*

Key technical areas

- Ordnance Automation
- Dual Stroke Rammer
- Thermal Management

BAE SYSTEMS

Key Success Factors

Need to demonstrate value for money vs. OTS options and “do nothing” option (4.5”)

- Develop
- UPC
- Integrati
- Through

Key integration aspects

- Ship Installation
- Fire Control
- Ammunition Stowage and Handling
- Land / Maritime Coherence

on

<u>Key Risk Area For TMF</u>

- **Raised in Options Report for FSC**
- **Not included in UK MoD research contract**
- **Ship builders require information to support PV Programmes**
- **Core Capability of US Combat Systems**
- **<u>So What?</u>**
    - **W&V PV committed in 2007 & 2008**
    - **Report passed to UK MoD and Naval Design Partnership**

Wider Strategic

- *Support Ho wider BAE customer t*

technical areas

- Ordnance Automation
- Dual Stroke Rammer
- Thermal Management

BAE SYSTEMS

Future Work

- Research test programme 2009
  - Ordnance firing demonstrator
    - Demonstrate strength of design
  - Dual full stroke rammer test rig demonstration
  - Thermal management test rig
    - Model validation
  - Laser Ignition demonstration

- Land based Integrated Demonstrator 2009 – 2011
  - Integration of ordnance and ammunition handling
  - Demonstrate system and technology maturity

- Full development 2011 – 2014

155 TMF Summary

- 155TMF is design that integrates the AS90 155mm ordnance with the Mk8 Naval Gun

- Key Attributes
  - Enhanced capability
  - Affordable through-life cost
  - Land and Naval fires coherence

- UK funded research programme to inform the Future Surface Combatant requirements
  - Mitigating technology risk
  - Excellent progress to date

Questions

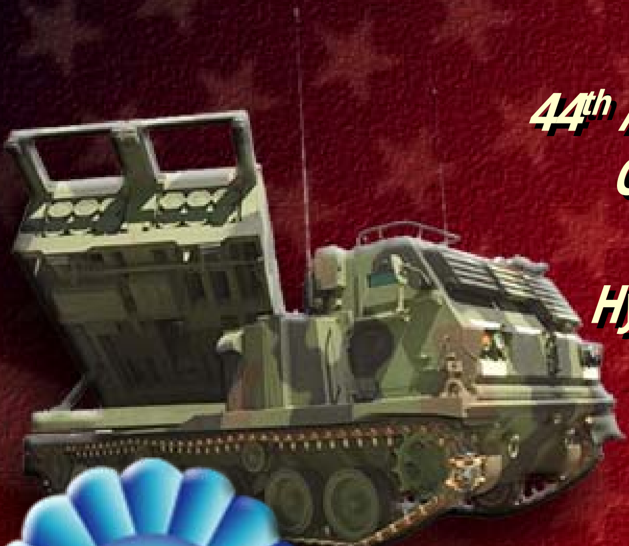
MISSILES AND SPACE

PROGRAM EXECUTIVE OFFICE

PRECISION FIRES ROCKET & MISSILE SYSTEMS

Precision Fires Rocket and Missile Systems

Presentation to
44th Annual Gun & Missile Systems
Conference and Exhibition



Hyatt Regency Crown Center
Kansas City, MO
6-9 April 2009

PSA
Precision Strike Association

Distribution A:
Approved for Public Release

Recipients of the 2008
William J. Perry Award

Darren McConnell
Director, Systems Engineering and Integration
Precision Fires Rocket and Missile Systems
Phone (256) 876-6128 (DSN 746)
Email: darren.mcconnell@msl.army.mil

Any Warfighter - Anywhere - All The Time

PFRMS Systems at War

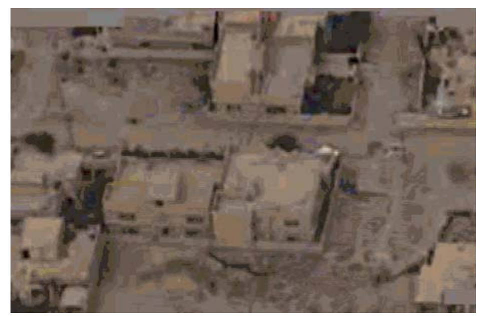
- All systems are supporting the Global War on Terrorism
- Currently supporting Operation Iraqi Freedom and Operation Enduring Freedom
- Performance is above Army Standards
- Launchers returning in excellent condition requiring only routine and minimal maintenance

M270A1
98% Readiness Rate

HIMARS
99% Readiness Rate

GMLRS Unitary
1,124 Rockets Fired
As of 5 Mar 09
98% Reliability

ATACMS
543 Missiles Fired
As of 10 Dec 09
98% Reliability



GMLRS-Unitary Rocket Usage in Theater

1,124 Total Rockets Fired As Of 5 Mar 2009

Who Shoots GMLRS-U:
US Army
USMC
UK

M270A1
M142
M270B1

US Army Missions

Who Requests GMLRS-U:
- *Army*
- *USMC*
- *Other*

How GMLRS-U is employed:
- *Troops in Contact*
- *Pre-Planned*

Environments employed:
- *Urban/COIN*
- *Other (TD/Test)*

Capability Gap: Persistent, responsive, all-weather, rapidly-deployable, long-range, surface-to-surface, precision-strike capability.

Description

- GPS-Augmented Inertial Guidance
- 200lb-Class HE IM-Compliant Warhead
- Multi-Fuze Selection (Point Detonating, Delay, Proximity)
- 15-70km Range

Current Targets

- Precisely Located/Mensurated Point targets
- Congested/Complex Urban Targets
- Targets in Areas Where Collateral Damage is of Concern

Effectiveness/Reliability

- BDA Shows High Level of Effectiveness
- Rare Reports of Minor Collateral Damage
- Reliability of US Army Missions: 98.68%

ATACMS QRU Usage In Theater

543 Total Missiles Fired as of 10 Dec 2008

Who uses ATACMS?

Army
Marines *Joint Operations*
USAF

How ATACMS is Employed:

Time-Sensitive Targets
Pre-Planned

Employment Environments:

Initial OIF Conflict
COIN

Mission Process

- **Target located by Multiple Sensors**
- **Target refined using Precision Strike Suite - Special Operation Forces or Mensuration via Rainstorm/Raindrop, etc.**
- **Passed to AFATDS for tactical fire control**
- **Launcher receives and executes mission**

Launcher Theater Accomplishments

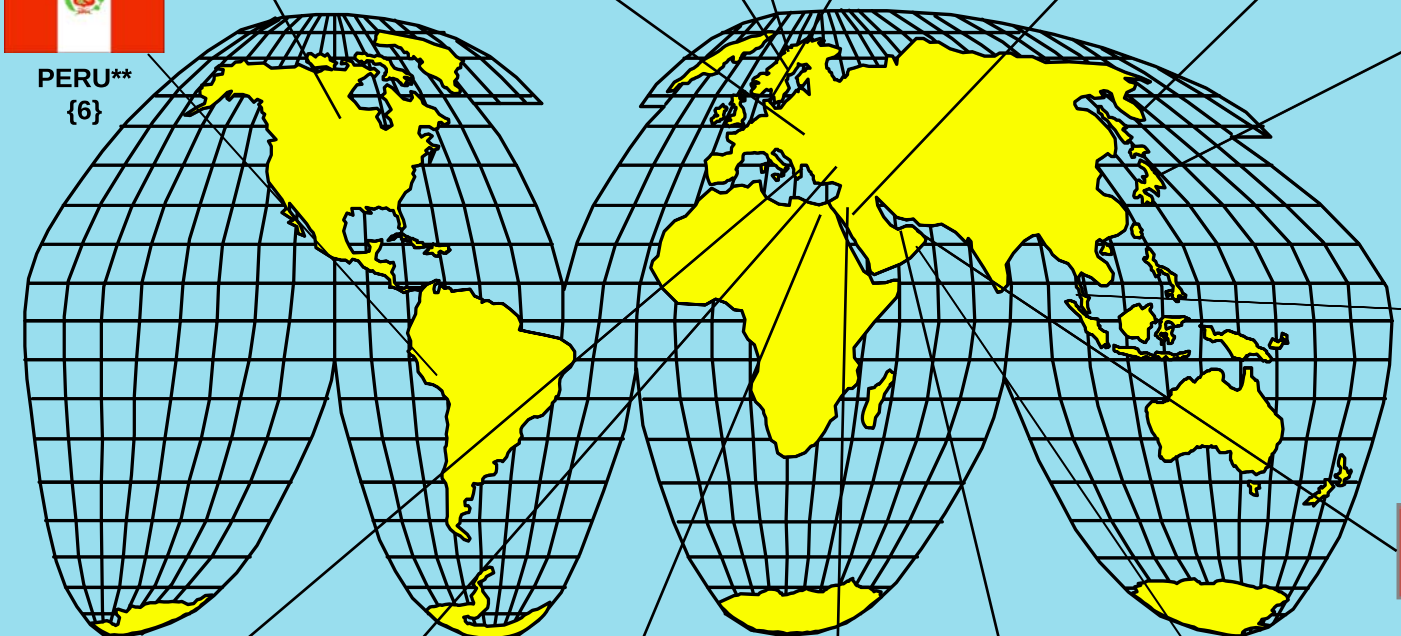
- All FAL variants (M270, M270A1, M270B1 and M142) have supported GWOT operations
- Launchers variants currently support both OIF and OEF operations
  - M142s support OIF / OEF
  - M270B1s support OEF
  - M270A1s support OIF
  - M142s support OIF

- Launchers deployed in Theatre continue to perform above Army Standards
  - Operational readiness exceeds 97%
  - Reliability is over 350 hours between System Abort Failures
  - No maintenance issues
- M142 and M270A1 launchers returning from both Theaters are in excellent condition requiring minimal Reset

MLRS Worldwide Third Party Sales

MOU PARTNERS

- US
- UK
- FRANCE
- GERMANY
- ITALY



Canada** {17}

SLOVAKIA |26| 1/

FINLAND (22)

NORWAY (12)

DENMARK (12)

JORDAN** {18}

SOUTH KOREA (48) [10] (A-220)

PERU** {6}

JAPAN (77) + [22] *

SINGAPORE {18}

UAE {20} (A-101)

GREECE (36) (A-100)

TURKEY (12) (A-71)

EGYPT (26)

ISRAEL (48)

BAHRAIN (9) + [6] (A-30)

OMAN** {20}

(A) ATACMS
{ } HIMARS
( ) M270
[ ] M270A1
* Co-Production

1/ | | RM-70 Modular Launchers / 810 M26 Rockets

** Potential

The Future for Cluster Munitions

<u>Requirement:</u> Suppress, neutralize, destroy various armored or soft, mobile or fixed, active or passive, precisely or imprecisely located, high-payoff area and point targets

<u>Cluster Munitions Policy Memo</u> (19 Jun 08)

- After 2018, cluster munitions must not produce >1% UXO; limit will not be waived
- No differentiation between types of UXO (hazardous or non-hazardous duds)
- All cluster munition stocks that exceed operational planning requirements will be removed from the inventory as soon as possible, but not later than Jun '09

<u>Self Destruct Fuze (SDF) Development and Performance</u>

- Previous UXO Requirement: <2% 20-60km; <4% <20km and >60km
  Does not Comply with the new DOD Policy
- GMLRS DPICM w/pSDF demonstrated "hazardous" dud rate of only 0.15%, overall UXO 3.7%:
  Does not comply with the new DOD Policy

Inventory and Operational Risks

Serviceable Rocket Inventory 2008-2019

	2008		2019
Munition	Available munitions	Range	Available munitions
M26 (DPICM)	360,192	32.5km	0
M26A2 (DPICM)	3,924	45.0km	0 ZERO
M30 (DPICM)	1,914	70.0km	0
M31A1 (Unitary)	204	70.0km	33,006

Operational Risks

- GMLRS AWP production schedule may not provide sufficient numbers by 2019 to support COCOM operational plans
- AMSAA/ARL approved models for AWP technologies

Program Overview

- Program composition
  - ACAT 1C with two variants
    - DPICM in Full Rate Production (FRP)
    - Unitary Completing LRIP headed to FRP Decision
  - Variants share documentation
    - APB
    - Common Funding (RDTE and Procurement) Lines

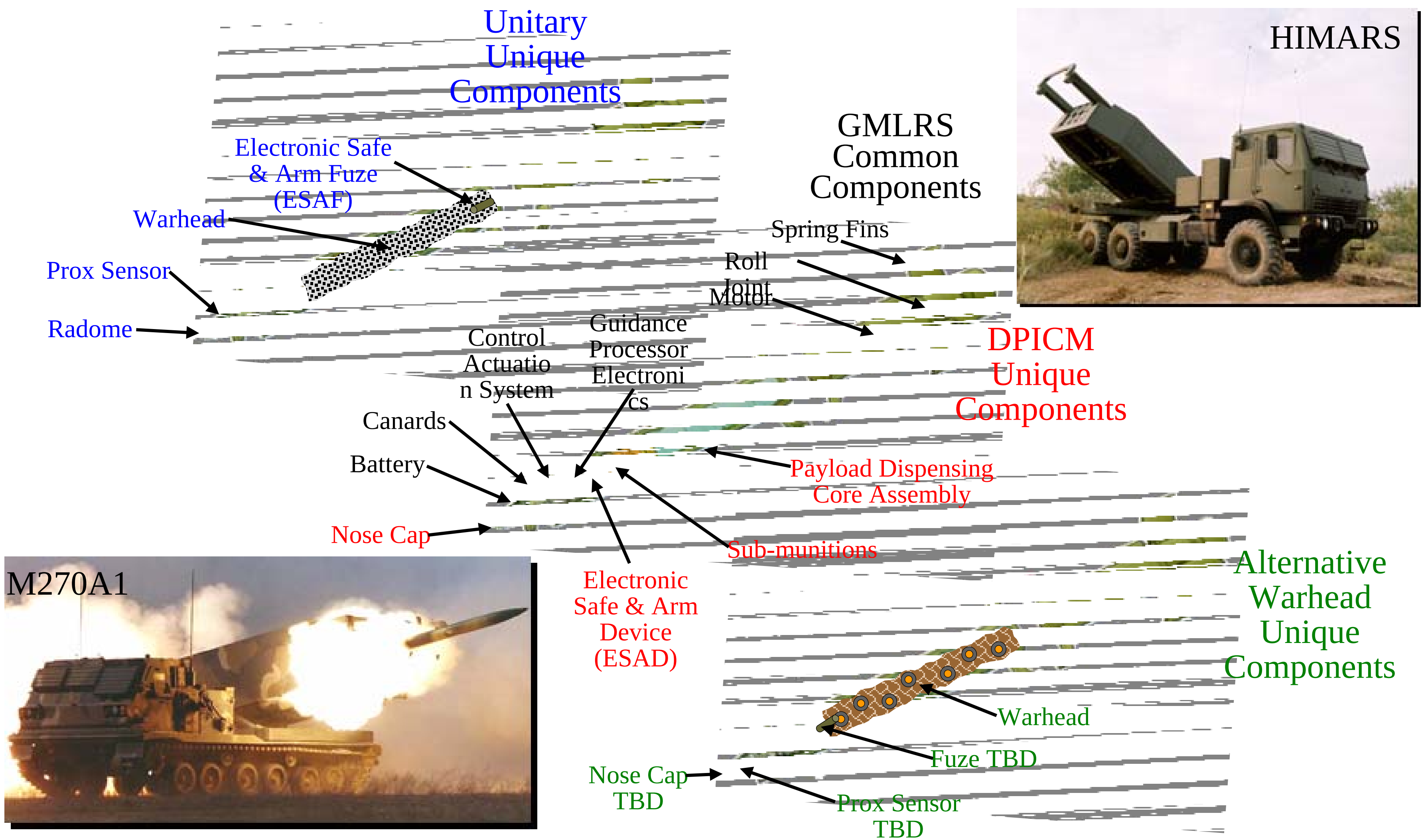
Second Order Effects

- Impact to APB
- Item C of Nunn-McCurdy ADM (April 2007)
- Future of DPICM Production
- Elimination of DPICM, impact on the USMC and FMS Customers

AWP Performance Parameters

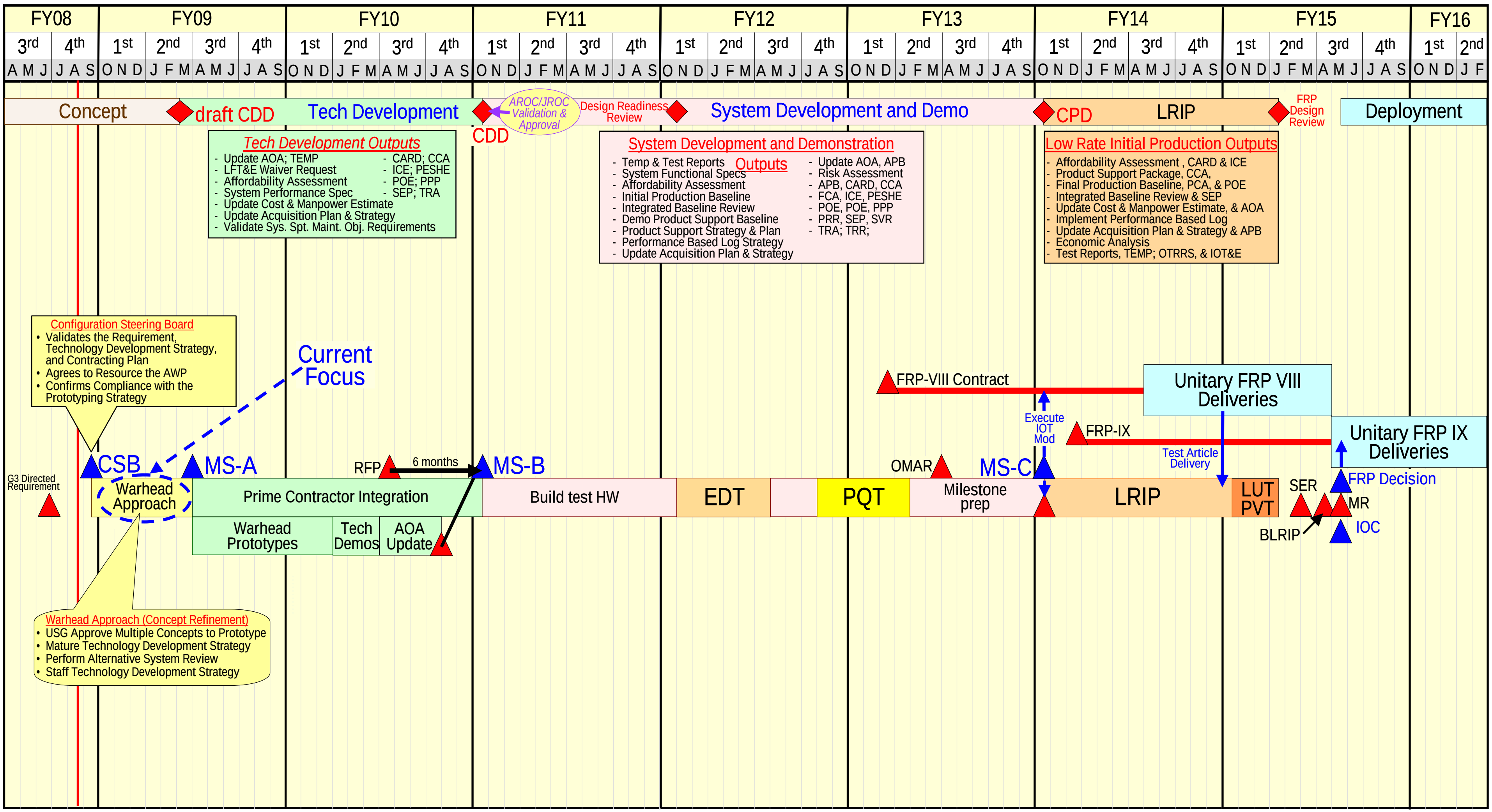
- Meets DPICM ORD requirements in servicing targets
- Produce no residual cluster munition UXO
- Achieve required warhead IM rating
- Compatible with the M270A1 and HIMARS Launchers

GMLRS System Description



UNCLASSIFIED

AWP Schedule Overview



Review of Eliminating DPICM

- Current pSDF (nor DPICM) is not compliant with DoD cluster munition policy
- Must demilitarize all non-compliant DPICMs after 2018; cost TBD
- UAE DPICM Procurement in FRP 4
- USMC Unexercised DPICM Option in FRP 4

Recommend Build Unitary in Lieu of DPICM FY09-FY13

Questions?

Demilitarization as a Systems Engineering Requirement

Mr. Gary Mescavage
Design for Demil IPT Lead
Demil & Environmental Technology Center, ARDEC
973-724-3349 gary.mescavage@us.army.mil

7 April 2009

Performs end of lifecycle management for conventional ammunition to include disposition and demilitarization

Outline

- The Demil & Disposal Requirement
- Demil Challenges
- Design for Demil (DFD)
- DFD Design Considerations
- Summary
- POCs

The Demil & Disposal Requirement

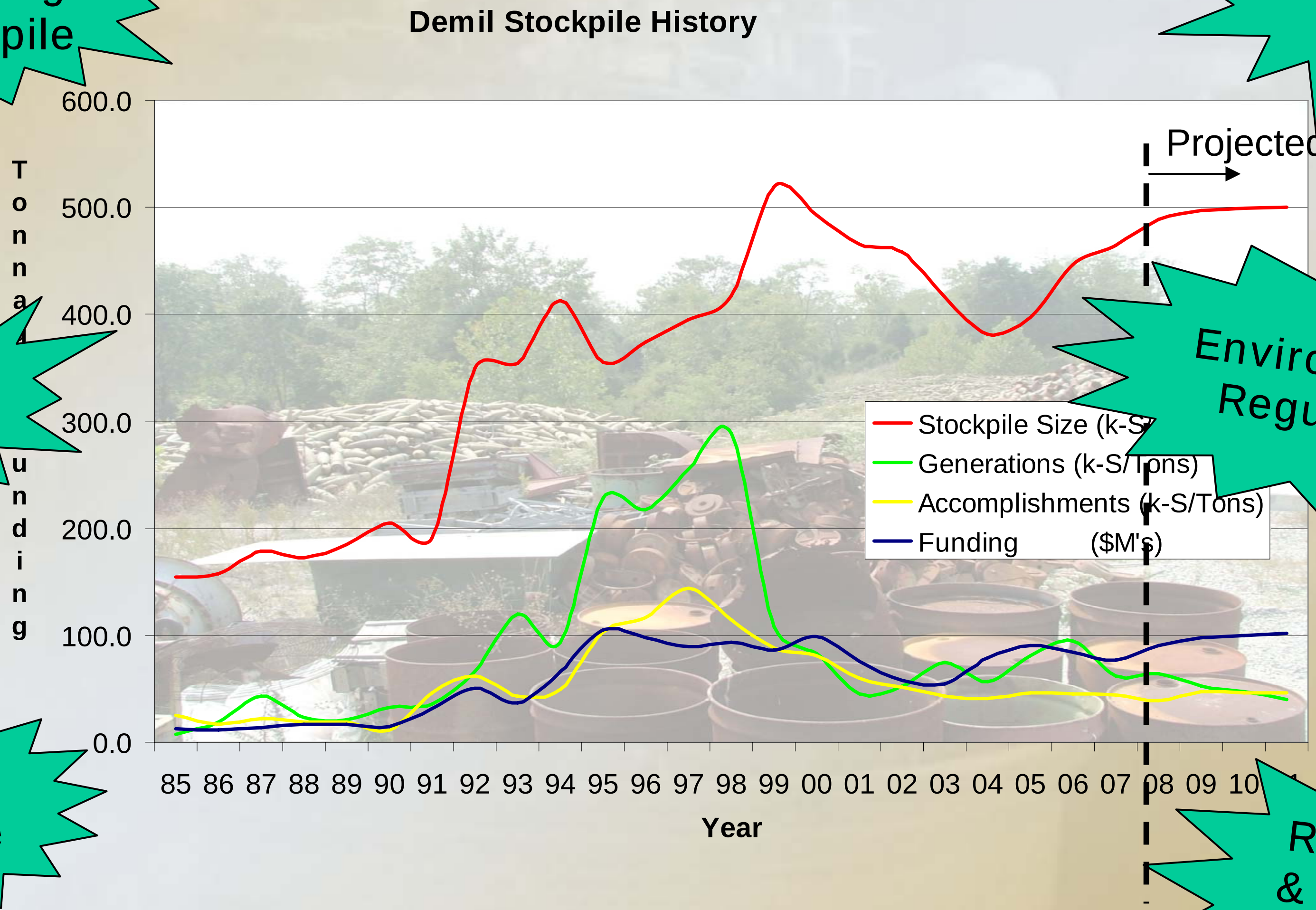
- **"At the end of its useful life, a system shall be *<u>demilitarized and disposed …</u>*" DoDI 5000.02**
- **Demil is "… destroying the military offensive or defensive advantages … to prevent the further use …" DoD 4160.12-M-1**
- **Responsibility for demil of all Services' conventional ammunition is assigned to the Army as the Single Manager for Conventional Ammunition (SMCA)**
- **The Army Product Manager for Demilitarization (PM Demil) executes the SMCA demil mission through the "Demilitarization Enterprise"**

Demil Execution: Then/Now/Future

Demil Challenges

Growing Stockpile

Increasing Cost



Limited Funding

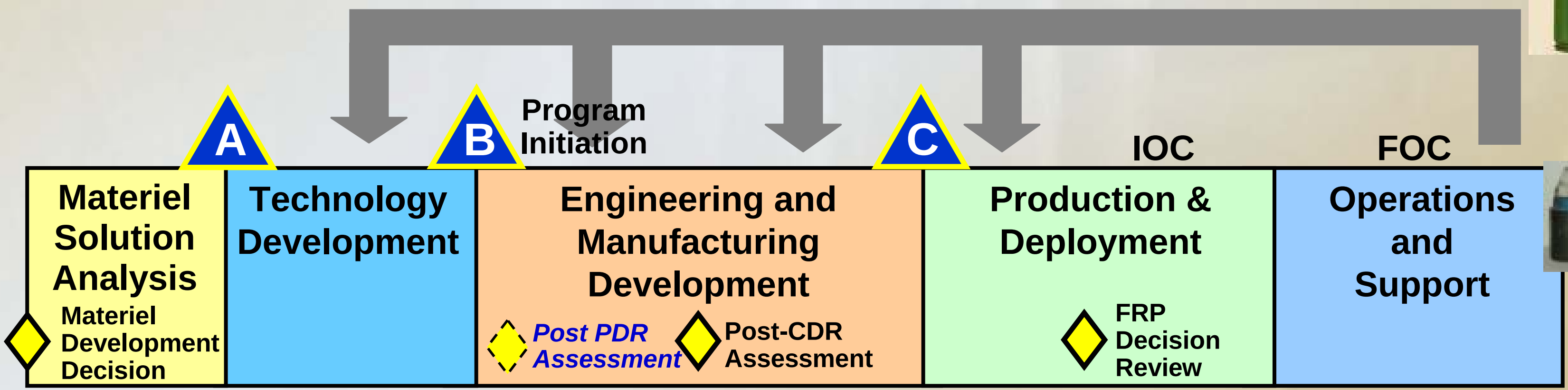
Environmental Regulations

Limited Storage

Recycle & Reuse

Design for Demil (DFD)

- Demil is a life cycle requirement that must be adequately addressed in design phase
- Goal: Include demil as a systems engineering requirement early to influence the design & positively impact future Demil execution



Why Design for Demil?

- **Traditionally, munition designers focus on item performance & may not be aware that design decisions can lead to difficult demil problems at the end of the item's life cycle**
- **In the past, OB/OD "took care of the problem"**
- ***Munition design historically had little impact on the ability to conduct effective and efficient demil (OB/OD)***
- **But things have changed …**

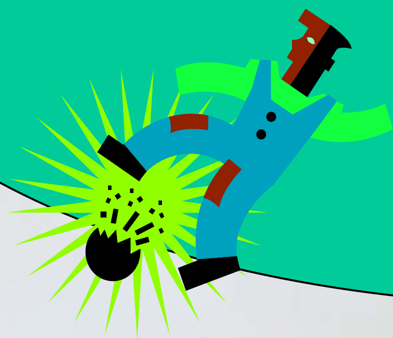
Design decisions made early in the life cycle have a significant impact on end of life cycle Demil operations!

Reduced OB/OD, Advanced Demil Tech.

Systems Engineering

Life Cycle Cost

Why DFD?



Environment

Readiness

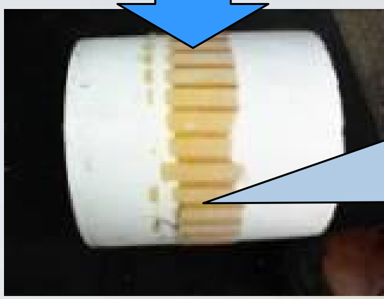
Safety

Resource, Recovery, & Recycling (R3)

DFD is a proactive approach to addressing future Demil challenges.

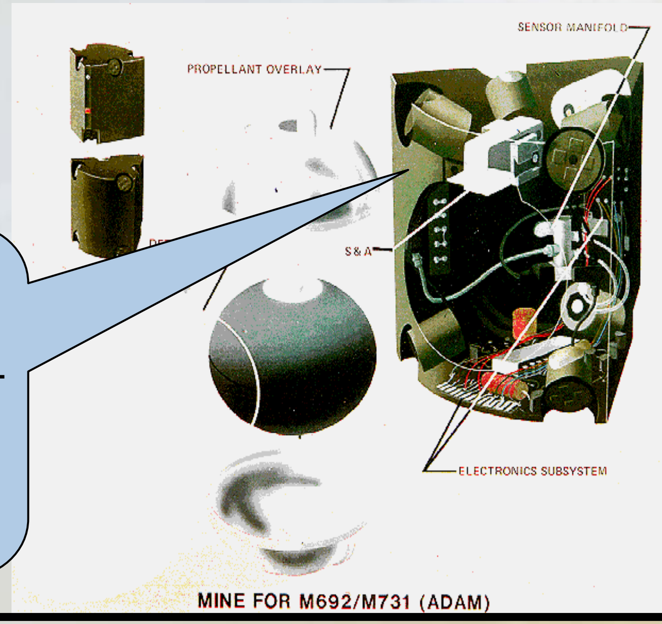
Design Impact on Demil

SPARROW 17A/B WARHEAD



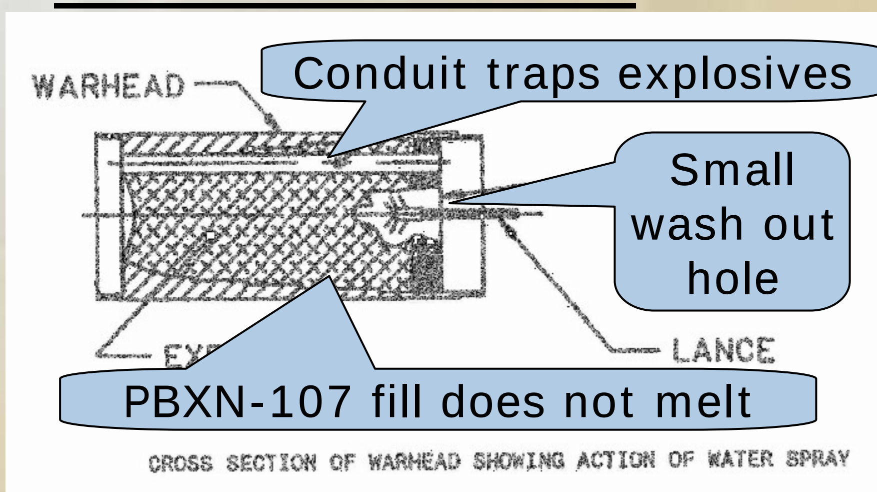
Glue requires extra process steps

ADAM MINE



Depleted Uranium Salt requiring $1M+ additional demil equipment

HARM WDU-21B NAVY



Conduit traps explosives

Small wash out hole

PBXN-107 fill does not melt

DFD Policy

- **DFD policy signed 4 Aug 08 by Mr. John Young, Undersecretary of Defense for Acquisition, Technology & Logistics**

THE UNDER SECRETARY OF DEFENSE
3010 DEFENSE PENTAGON
WASHINGTON, DC 20301-3010

[illegible]
TECHNOLOGY
AND LOGISTICS

AUG [illegible] 2008

MEMORANDUM FOR SECRETARIES OF THE MILITARY DEPARTMENTS
CHAIRMAN OF THE JOINT CHIEFS OF STAFF
COMMANDER, U.S. SPECIAL OPERATIONS COMMAND
DIRECTOR, OPERATIONAL TEST & EVALUATION
DIRECTORS OF THE DEFENSE AGENCIES

SUBJECT: Design for Demilitarization of Conventional Ammunition

Demilitarization is an ever-present problem in the Department – especially for conventional ammunition due to the inherent safety hazards and environmental classification as a hazardous material. Conventional ammunition, for the purposes of this memorandum, is defined as (in DoD Directive 5160.65, Single Manager for Conventional Ammunition) encompassing any item containing propellants, explosives, or pyrotechnics.

The current U.S. military-based demilitarization stockpile of conventional ammunition is approximately 500 thousand short tons, and growing. This represents a cost to the Department not only in dollars, but also in operational readiness. Conventional ammunition systems that do not incorporate demilitarization considerations into their design are prone to present a variety of challenges at the end of the life cycle during demilitarization operations. These systems increase life cycle costs and create safety and environmental issues. They also create missed opportunities to recover value through reclamation and reuse of conventional ammunition materials and components. The Acquisition Community has an opportunity to address proactively these problems for future conventional ammunition.

Good systems engineering addresses all aspects of the life cycle, including systems' demilitarization and disposal. During system design, conventional ammunition designers can facilitate optimal demilitarization methods and resource reclamation and reuse by implementing Design for Demilitarization. This includes designs for conventional ammunition that: facilitate disassembly and access to energetic materials; use energetic materials and components having reclamation or reuse potential; efficiently accommodate existing demilitarization processes; reduce the use of environmentally sensitive materials; and enhance safety for demilitarization operators.

To implement Design for Demilitarization, the Military Departments, Defense Agencies, and the U.S. Special Operations Command will include in their acquisition documentation for all pending (i.e., pre-Milestone A) and future conventional ammunition programs how they intend to address demilitarization design requirements throughout system design. Specific requirements for Design for Demilitarization of conventional ammunition are attached.

This policy supports the Department's objectives in Total Life Cycle Management. While this effort focuses primarily on conventional ammunition, Design for Demilitarization is a good systems engineering practice that should be applied to all defense programs.

My point of contact is Mr. Jose Gonzalez at 703-693-9203. Additional assistance can also be obtained from Mr. Gary Muscavage, with the Armament Research, Development, and Engineering Center, at 973-724-3349.

John J. Young, Jr.

Attachment:
As stated

2

"Good systems engineering addresses all aspects of the life cycle, including systems' demilitarization and disposal."

DFD Policy

- **DoD I 5000.02 (Dec 8, 2008) amended (para. 8.c.(2)) to increase emphasis on demil consideration during design …**

(2) Disposal. At the end of its useful life, a system shall be demilitarized and disposed of in accordance with all legal and regulatory requirements and policy relating to safety (including explosives safety), security, and the environment. **<u>During the design process, PMs shall</u>** document hazardous materials contained in the system in the Programmatic Environment, Safety, and Occupational Health Evaluation (PESHE) (see Section 6 in Enclosure 12), and shall **<u>estimate and plan for the system's demilitarization and safe disposal. The demilitarization of conventional ammunition (including any item containing propellants, explosives, or pyrotechnics) shall be considered during system design.</u>**

Demil Plan vs Design for Demil

Demil Plan	$\neq$	Design for Demil
➢ Typically done late in the design		➢ Done throughout design
➢ Prescribes a procedure for demil		➢ Influences the design for efficient demil
➢ Afterthought		➢ Forethought
➢ Reactive		➢ Proactive

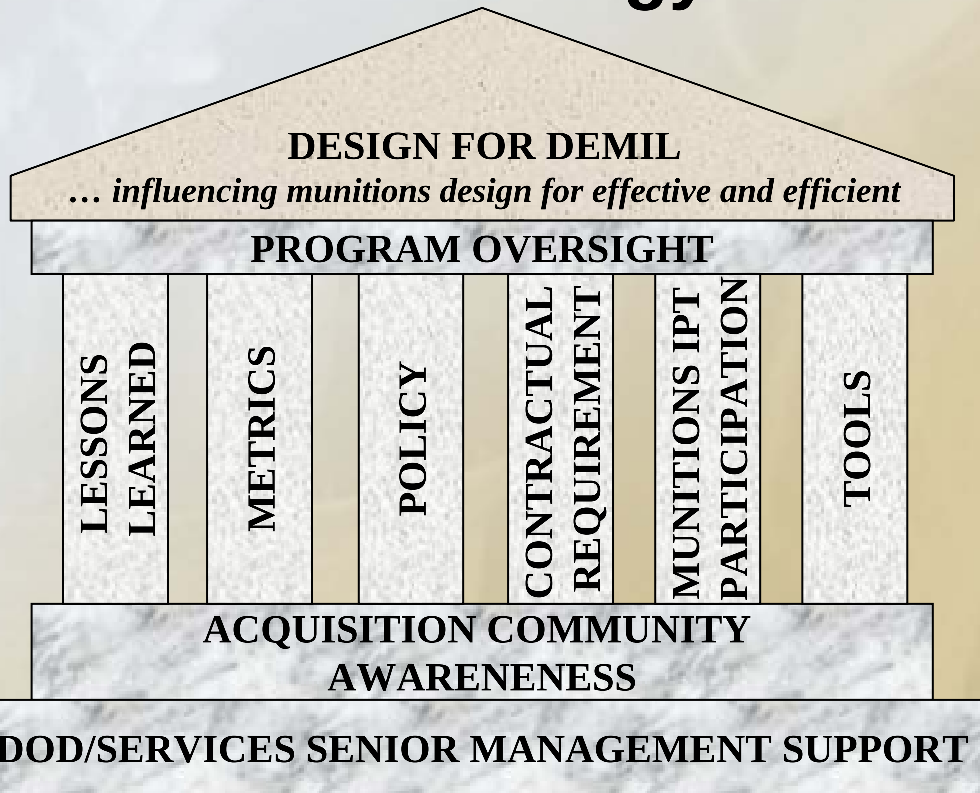
Demil Plans can encourage but do not assure design for demil!

Item Performance

- **Design for Demil is not intended to detract from achieving item performance**
- **Design trade offs will be handled by the Item PM**
- **Low cost design changes that do not impact performance could be made … if demil is included up front and early as a requirement**

Design for Demil IPT & Implementation

- DFD is a key strategic goal of the PEO Ammo approved Demil Enterprise Strategic Plan
- Multi-Service DFD Integrated Process Team (IPT) chartered to establish DFD strategy and approach
- Multi-faceted approach is being pursued to implement DFD



DFD Policy Requirements

"… include in acquisition documentation how (you) intend to address demilitarization design requirements throughout system design."

- **Define a demilitarization design requirement**
  - ✓ **Include in acquisition documentation**
  - ✓ **Include throughout systems engineering process**
- **Address DFD activities in program reviews**
- **Include valid estimates of demilitarization in Life Cycle Cost/affordability estimates**
- **Develop a demil plan demonstrating DFD features**
- **Include in Developmental Testing**

DFD Design Considerations

- Easy disassembly
- Easy access to and removal of energetics
- Materials & components that are reusable, recyclable, and non-hazardous
- Accommodates existing Demil capabilities and avoids special tools
- Consider demil operator involvement

Key: Incorporate DFD considerations early to mitigate Demil impact and cost while not affecting mission capability

Summary

- Demil is a life cycle requirement that must be included early in the systems engineering process
- Early ammunition design decisions impact Demilitarization operations
- DFD is a policy requirement and a proactive way to mitigate future Demil challenges
- Forethought during early development will reduce the cost associated with end of life cycle management, with little impact to development cost

DFD POCs

- Mr. Orest Hrycak, OPM Demil Chief Engineer

  973-724-6937 orest.hrycak@us.army.mil

- Mr. Gary Mescavage, DFD IPT Lead

  Demil & Environmental Technology Division, EWETD, ARDEC

  973-724-3349 gary.mescavage@us.army.mil

https://www.pica.army.mil/pmdemil

U.S. Army Research, Development and Engineering Command
Benét Laboratories

TECHNOLOGY DRIVEN. WARFIGHTER FOCUSED.

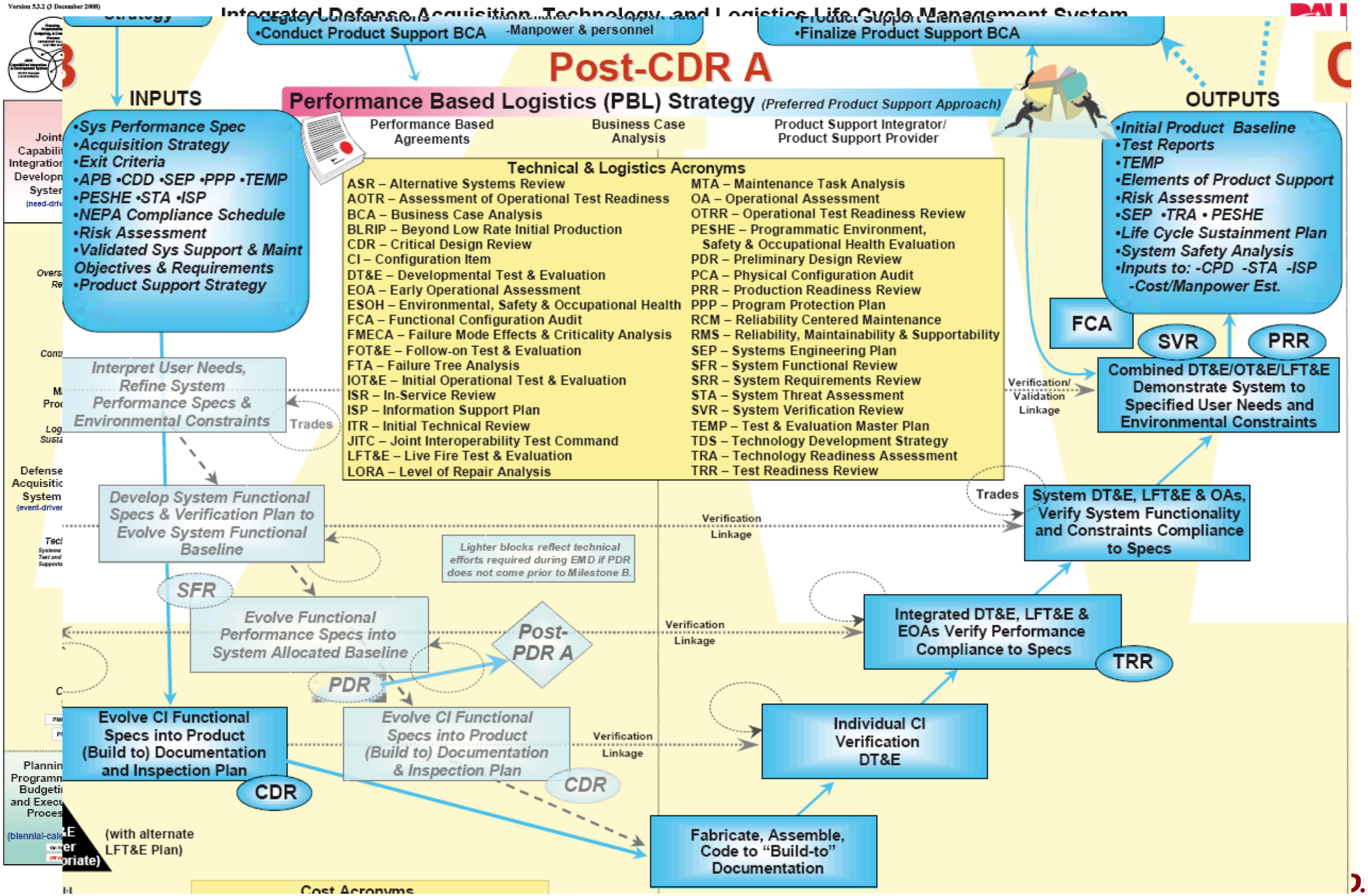
Gun Assembly Safety Certification – US Approach
Briefing for the NDIA
26 March 2009

David C. Smith, P.E.
Supervisory Mechanical Engineer

Gun Assembly Safety Certification
Agenda

- Acquisition Process
- Weapon Safety Certification
- Gun Qualification Tests
- Typical Gun Test Program
- Test Supporting Elements
- Certification

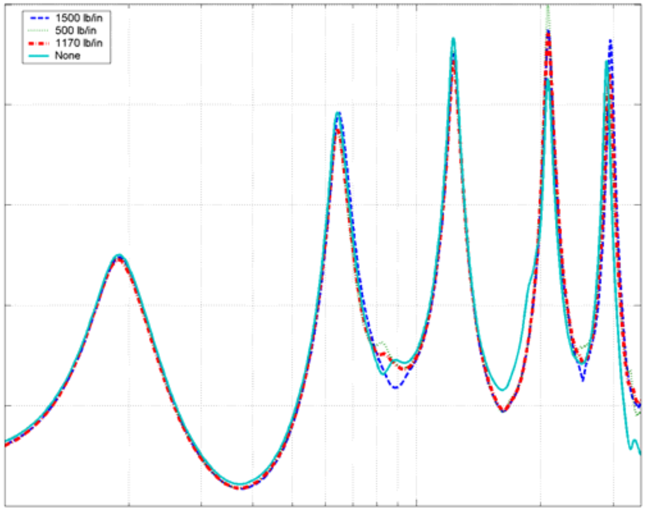
105 MM M137A1
Cannon mounted in
AC-130 Gunship
(Photos: Janes Weekly)


Version 5.3.2 (3 December 2008)
Integrated Defense Acquisition, Technology, and Logistics Life Cycle Management System
•Conduct Product Support BCA
-Manpower & personnel
•Finalize Product Support BCA
Post-CDR A
INPUTS
•Sys Performance Spec
•Acquisition Strategy
•Exit Criteria
•APB •CDD •SEP •PPP •TEMP
•PESHE •STA •ISP
•NEPA Compliance Schedule
•Risk Assessment
•Validated Sys Support & Maint Objectives & Requirements
•Product Support Strategy
Performance Based Logistics (PBL) Strategy (Preferred Product Support Approach)
Performance Based Agreements
Business Case Analysis
Product Support Integrator/ Product Support Provider
OUTPUTS
•Initial Product Baseline
•Test Reports
•TEMP
•Elements of Product Support
•Risk Assessment
•SEP •TRA • PESHE
•Life Cycle Sustainment Plan
•System Safety Analysis
•Inputs to: -CPD -STA -ISP
-Cost/Manpower Est.
Technical & Logistics Acronyms
ASR – Alternative Systems Review
AOTR – Assessment of Operational Test Readiness
BCA – Business Case Analysis
BLRIP – Beyond Low Rate Initial Production
CDR – Critical Design Review
CI – Configuration Item
DT&E – Developmental Test & Evaluation
EOA – Early Operational Assessment
ESOH – Environmental, Safety & Occupational Health
FCA – Functional Configuration Audit
FMECA – Failure Mode Effects & Criticality Analysis
FOT&E – Follow-on Test & Evaluation
FTA – Failure Tree Analysis
IOT&E – Initial Operational Test & Evaluation
ISR – In-Service Review
ISP – Information Support Plan
ITR – Initial Technical Review
JITC – Joint Interoperability Test Command
LFT&E – Live Fire Test & Evaluation
LORA – Level of Repair Analysis
MTA – Maintenance Task Analysis
OA – Operational Assessment
OTRR – Operational Test Readiness Review
PESHE – Programmatic Environment, Safety & Occupational Health Evaluation
PDR – Preliminary Design Review
PCA – Physical Configuration Audit
PRR – Production Readiness Review
PPP – Program Protection Plan
RCM – Reliability Centered Maintenance
RMS – Reliability, Maintainability & Supportability
SEP – Systems Engineering Plan
SFR – System Functional Review
SRR – System Requirements Review
STA – System Threat Assessment
SVR – System Verification Review
TEMP – Test & Evaluation Master Plan
TDS – Technology Development Strategy
TRA – Technology Readiness Assessment
TRR – Test Readiness Review
FCA
SVR
PRR
Combined DT&E/OT&E/LFT&E Demonstrate System to Specified User Needs and Environmental Constraints
Verification/ Validation Linkage
Interpret User Needs, Refine System Performance Specs & Environmental Constraints
Trades
Develop System Functional Specs & Verification Plan to Evolve System Functional Baseline
Verification Linkage
Trades
System DT&E, LFT&E & OAs, Verify System Functionality and Constraints Compliance to Specs
Lighter blocks reflect technical efforts required during EMD if PDR does not come prior to Milestone B.
SFR
Evolve Functional Performance Specs into System Allocated Baseline
Post-PDR A
Verification Linkage
Integrated DT&E, LFT&E & EOAs Verify Performance Compliance to Specs
TRR
PDR
Evolve CI Functional Specs into Product (Build to) Documentation and Inspection Plan
Evolve CI Functional Specs into Product (Build to) Documentation & Inspection Plan
Verification Linkage
Individual CI Verification DT&E
CDR
CDR
(with alternate LFT&E Plan)
Fabricate, Assemble, Code to "Build-to" Documentation
Cost Acronyms

Acquisition Process
Weapon Development Programs

- Most testing and safety evaluations done during System Design & Development Phase (now called Engineering & Manufacturing Development)
- Every type of product will have differing tests, standards & requirements
- Weapons Systems have a reasonably well defined set of safety standards and tests, oriented around NATO Standardization Agreements (STANAGs) and International Test Operational Procedures (ITOPs)
- Performance and Operational Tests are individually designed and executed for each System.

Natural Frequency Response Testing of 120 MM Tube



- Given the nature and expense of testing it is usually quite impossible to completely isolate safety testing from other required development testing for issues such as reliability, maintainability, performance evaluation. As a result:
  - Conflicts often arise when failures occur in test hardware – do we continue testing and risk further failures or do we stop tests to correct the problems
- A properly laid out development program has a Test & Evaluation Master Plan (TEMP) developed <u>and coordinated</u> at the very beginning of the program (as early as the concept phase) that addresses which requirements – safety and performance – will be assessed addressed at what phase of testing.
- Failure Mode Effects Criticality Analysis (FMECA) – While this is primarily a reliability tool, it can also serve as a test & safety assessment tool. Example shown later
- Large caliber guns require expensive, long lead processes to obtain forgings, parts, etc, and as such, their development will precede most of the other vehicle developments, to allow the safety cert activities to occur in timely fashion to allow other vehicle developments and tests to proceed.
- Gun Assemblies are typically not safety certified by themselves. They are normally tested and certified as part of a vehicle system. As such they typically are integrated with vehicle test & development activities. Conversely, use of the same gun in a different vehicle will require some level of re-certification (testing or evaluation)

- What is a Gun Safety Certification?
  - Certification by an independent (from the developer) evaluator that no significant hazards exist.
  - Certification is supported by analysis, testing, validations submitted by the developer.
  - Certification is required before military personnel are allowed to be in the Vehicle when the weapon is fired. (live fire)
  - Certification is required to pass Milestone (C)
- Testing is required to obtain a Safety Certification on a Gun.
  - Governed by ITOPs, STANAGs, MIL STDs (see next page)
  - Tailored for each weapon and each program

155 MM M284 (left) on US M109A6 (Iraq 2007) – 155 MM M185A2 (below) on Israeli M109 (Gaza 2003)

Weapon Safety Certification References

- STANAGs:
  - 4110; Definition Of Pressure Terms And Their Interrelationship For Use In The Design And Proof Of Cannons Or Mortars And Ammunition
  - 4385; 120 MM Tank Ammunition
  - 4493; Tank Ammunition Safety & Suitability for Service
  - 4650; International Test Operation Procedures (ITOP) On Testing Of Large Caliber Weapons And Ammunition
- ITOPs
  - 3-2-829 Cannon Safety Test
  - 3-2-050 Testing Of Mortar Systems
  - 3-2-500 Weapon Characteristics
  - 3-2-506(1) Artillery Self-propelled And Towed
  - 3-2-506(2) Tank Cannon & Recoil Mechanism
  - 3-2-605 Tank System Accuracy Reference Firing
  - 4-2-504(1) Safety Testing Of Artillery Ammunition
  - 4-2-504(2) Safety Testing Of Tank Ammunition
- MIL STDs
  - MIL STD 882; System Safety Program Management
  - MIL-STD-1474D, Noise Limits

- Roles:
  - Development Agency – Gun Assembly (Benet) & Vehicle Developer
  - US Army Test Center(s) – Testers (Developmental and Operational)
  - US Army Training & Doctrine Command (TRADOC) – Requirements Developer
  - Project Manager – Customer (for the US Soldier)
  - US Army Developmental Test Command (DTC) – Independent Evaluation and Certification
- Prior to test, Developer completes”
    - Failure Mode Effects Criticality Analysis (FMECA): Provides clues to what highest safety and reliablity isses will be
    - Safety Assessment Report: Provides an assessment of the gun to the tester and certification agencies, matures with increasing testing.
    - Health Hazard Assessment Report (HHAR): Draft prior to testing, increasing maturity during testing, finalized at end of testing. Provides certification that all hazards mitigated and product is safe for use.
    - Test & Evaluation Master Plan: Provides a roadmap of all tests, when requirements will be assessed, what methodology used, what standards to be used.

Gun Qualification Tests

- Summary:
  - Proof & Baseline Tests
  - Fatigue Test
  - Mount Safety Test
  - Wear Test
  - Strength of Design
  - Toxic Fumes
  - Noise and Blast Overpressure
  - Safe Maximum Pressure *

120 MM M256 Gun Firing off M1A1 Tank in Iraq.

* not yet a required test

- Proof & Baseline:
  - Cannons:
    - All prototype cannons are proofed with 5 to 7 rounds*
    - Proof rounds typically utilize adjustments to ensure proof pressure achieved
    - Cannon must be inspected before and after proofing
    - Direct Fire cannons are also baselined for precision - 10 rounds per cannon per round type to be tested.
    - Reference:
      - International Test Operations Procedure (ITOP) 3-2-829, “Cannon Safety Test,” 23 Oct 92
      - International Test Operations Procedure (ITOP) 3-2-605, “Tank System Accuracy/Reference Firing”

* Production Gun Assemblies are also proofed

- Proof & Baseline (cont'd):
  - Mounts:
    - All prototype gun mounts are proofed with 3-5 rounds*
    - Maximum impulse conditions (round and elevation) must be met
    - Mount is inspected before and after proofing
    - Reference:
      - International Test Operations Procedure ITOP 3-2-506(2) "Tank Cannon & Recoil Mechanisms"
      - International Test Operations Procedure ITOP 3-2-506(1) "Artillery (Self-Propelled and Towed)"

* Production Gun Assemblies are also proofed

- Fatigue Test
  - Required for all new gun systems
  - Required if significant modifications have been made in fatigue-sensitive areas of the tube and/or breech as a basic design change, provided:
    - Sufficient experience with service use indicates change is in a non-critical area
    - And, Modeling and Analysis shows change won’t affect performance
  - New Gun - Interim Fatigue Life Test
    - Two tubes and breeches are fired ~500 rounds and are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test, but should provide maximum fatigue impact (pressure))
  - New Gun - Final Fatigue Life Test
    - Four additional tubes are fired ~500 rounds. Tubes and four additional breeches are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test.)
  - Existing Gun - Two tubes and breeches are fired ~500 rounds and are cycled to failure in fatigue simulators. (Rounds are not dedicated to this test.)
  - ITOP 3-2-829
  - (Test phases are typically referred to as ‘Pre-Fatigue Testing’, and ‘Laboratory Fatigue Testing’)

- Mount Safety Test
  - Weapon Firing Phase
    - Test the overall performance of the mount at various elevations – 50 rounds
  - Recoil Firing Phase
    - Test the performance of the recoil system at various elevations and with ammunition conditioned to temperature extremes – 50 rounds
  - Extreme Temperature Phase
    - The mount is conditioned to temperature extremes and fired. – 22 rounds
  - ITOP 3-2-506(2), Tank Cannon and Recoil Mechanism

Gun Qualification Tests

- Wear Test
  - Two tubes are fired until range or accuracy criteria are not met. (Rounds are not dedicated to this test, but a mix of rounds is typically used to assess total life)
  - Testing is usually conducted in groups of ‘expenditure’ rounds and groups of ‘accuracy’ rounds.
  - Reference: ITOP 3-2-829
- Strength of Design
  - Verify that ammunition can successfully withstand the maximum launch forces – 30 rounds for each type of ammunition to be tested.
  - ITOP 4-2-504(2) Safety Testing of Tank Ammunition)
- Toxic Fumes
  - Vehicle is instrumented and the concentration of gases produced as a result of firing is measured at various locations - 20 to 30 rounds.
  - ITOP 2-2-614, Toxic Hazards Tests for Vehicles and Other Equipment
- Noise and Blast Overpressure
  - Noise and blast overpressure are measured at various locations around the vehicle – 20 to 30 rounds.
  - ITOP 4-2-822, Electronic Measurement of Airblast Overpressure and Impulse Noise, and MIL-STD-1474D, Noise Limits

- Ammunition Requalification/Autoloader Qualification
  - Autoloader Vibration - Ammunition is placed in the autoloader, vibrated on a vibration table and cycled through the autoloader – 20 rounds for each type of ammunition to be tested. (ITOP 3-2-051, “Automatic Loaders for Tank Systems)
  - Sequential Rough Handling - The following tests are conducted in succession, one iteration with rounds conditioned to high temperature, another with rounds conditioned to low temperature:
    - 2.1 Meter Drop
    - Logistic Vibration
    - 1.5 Meter Drop
    - Autoloader Cycling
  - Firing - Number or rounds depends on packaging configuration – 90 to 100 rounds for each type of ammunition tested. (ITOP 4-2-504(2) and ITOP 4-2-602, “Rough Handling Tests)

- Ammunition Requalification/Autoloader Qualification (cont'd)
  – Sequential Life Cycle - Following tests are conducted in succession, one iteration with rounds conditioned to high temperature, another with rounds conditioned to low temperature:
    - Tactical Vibration
    - Hot/Dry Storage Cycle (half of the rounds conditioned to high temperature)
    - High Humidity Cycle (the other half of the rounds conditioned to high temperature
    - Cold Storage Cycle (rounds conditioned to low temperature only)
    - Hull Vibration
    - Autoloader Vibration
    - Chamber/Extract Cycles
  – Firing - Number of rounds depends on whether the projectiles contain explosive elements – between 100 and 140 rounds for each type of ammunition to be tested. (ITOP 4-2-504(2) and ITOP 3-2-051)

- Worn Tube
  - Fire rounds in a worn tube to verify that ammunition can function safely in a worn tube. For rounds with explosive elements in the projectiles – 70 rounds for each type of ammunition to be tested. Other rounds – 20 rounds for each type of ammunition to be tested.
  - ITOP 4-2-504(2)

- Safe Maximum Pressure:
  - not governed by an ITOP
  - Rounds are fired at increasing pressure levels until SMP is observed by plastically deforming cannon
  - Hazards and gun performance is assessed and used to define hazard levels and resultant operational procedures.

- Cannon Safety:
  - – Firing Tests
    - Cannon Safety Test #1 - Pre Fatigue
    - Cannon Safety Test #2 - Pre Fatigue
    - Cannon Safety Test #3 - Pre Fatigue
    - Cannon Safety Test #4 - Pre Fatigue
    - Cannon Safety Test #5 / Tube Wear Test#1
    - Cannon Safety Test #6 / Tube Wear Test#2
    - Laboratory Fatigue Tests
      - – 6 Breech Assemblies –
      - – 6 Gun Tubes –

ITOP 3-2-829

- Gun Mount & Recoil System Tests
  - – Firing Tests
    - Basic Firing Program – zero QE
    - Basic Firing Program – Max/Min QE
    - Extreme Temperature Test
  - – Laboratory Tests
    - Two Recoil Durability Tests @ RIA

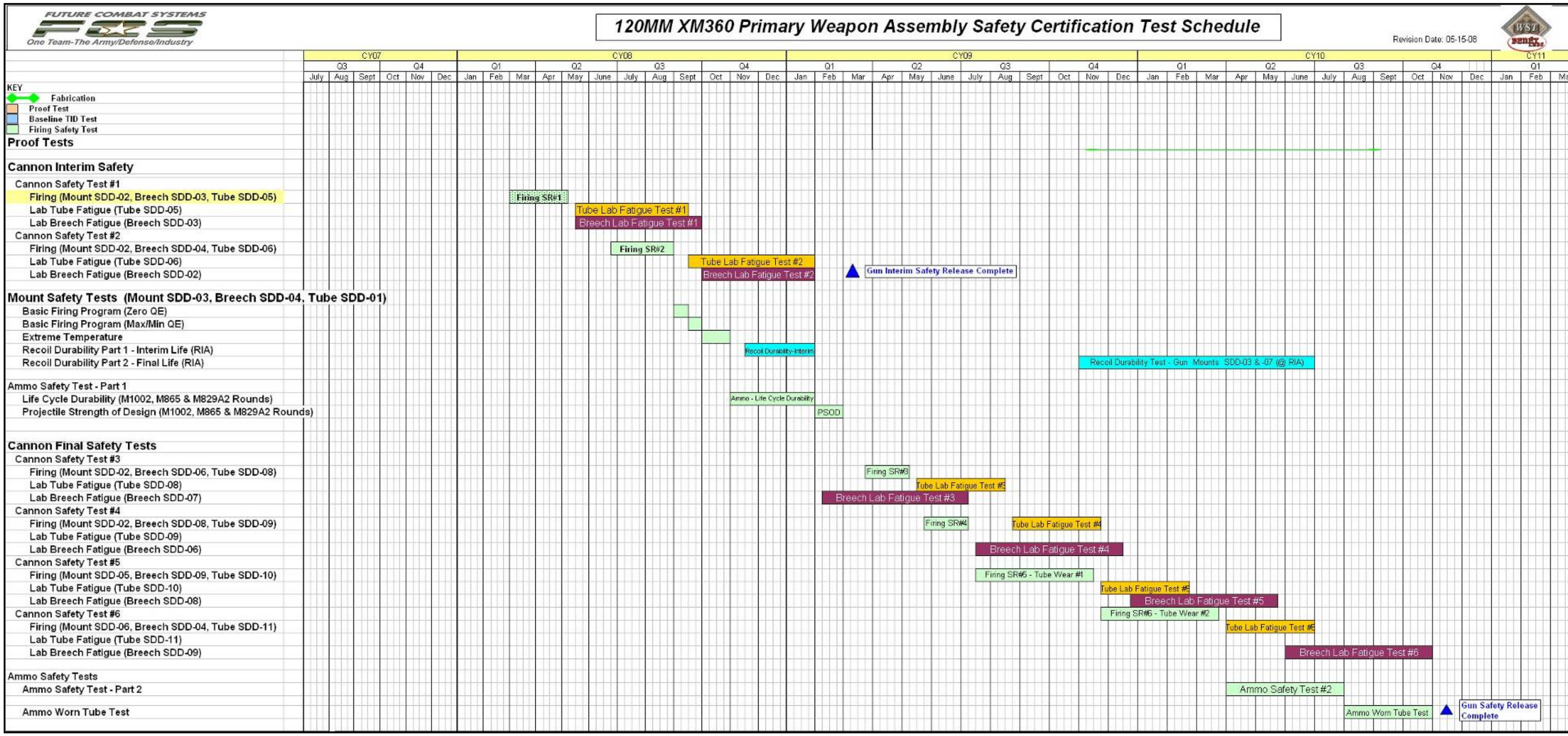
ITOP 3-2-506(2)

- Ammunition Safety:
  - Ammo Safety Test #1
    - Projectile Strength of Design Test
    - Cannon Strength of Design Test
    - Abbreviated Life Cycle Durability Test
    - Testing to be conducted on M1002, M865 & M829A2 Rounds
  - Ammo Safety Test #2
    - Same Tests as Test #1, but with remaining Rounds
  - Ammunition Worn Tube Test (July – Oct 2010)
    - 30 (Non-HE) to 70 (HE) rounds fired from a 4th quarter Tube.
    - Test determines if rounds functioned properly.
    - To be conducted on all Rounds

- Ammo Handling, BOP, and Toxic Fumes Tests will be conducted during vehicle tests

ITOP 4-2-504(2)

Example Test Overview



[TEMP - Firing Test Plans 05-16-08.pdf]

- Specific Test Layout – Safety Test 2
  - Objective: To provide the 2nd of two Gun Tube Fatigue Test Samples for use in the Establishment of an Interim Fatigue Life per ITOP 3-2-829 for the Weapon Assembly . This test will consist of firing 500 rounds of ammunition capable of producing pressures in accordance with STANAG 4385. 500 rounds will be fired per a request for an interim safe life of 500 rounds. This is the 2nd of six Safety Tests which will be used to request a Final Safety Release on the XM360 Gun Assembly. This will be accomplished by performing the following series of tests:
    - Conduct Target Impact Dispersion (TID) Testing
    - Conduct Field Blast Over Pressure (BOP) Testing.
    - Conduct Expenditure Testing.
    - Conduct Post Test Inspections.
    - Evaluate gun performance differences when the gun is fired with and without the Breech Counterweights.
    - Monitor the overall performance of the Gun System.
    - Conduct Dynamic Muzzle Reference System and Gyro Testing per customer test plans noted in Appendix E.

US ARMY RDECOM

Example Test Overview

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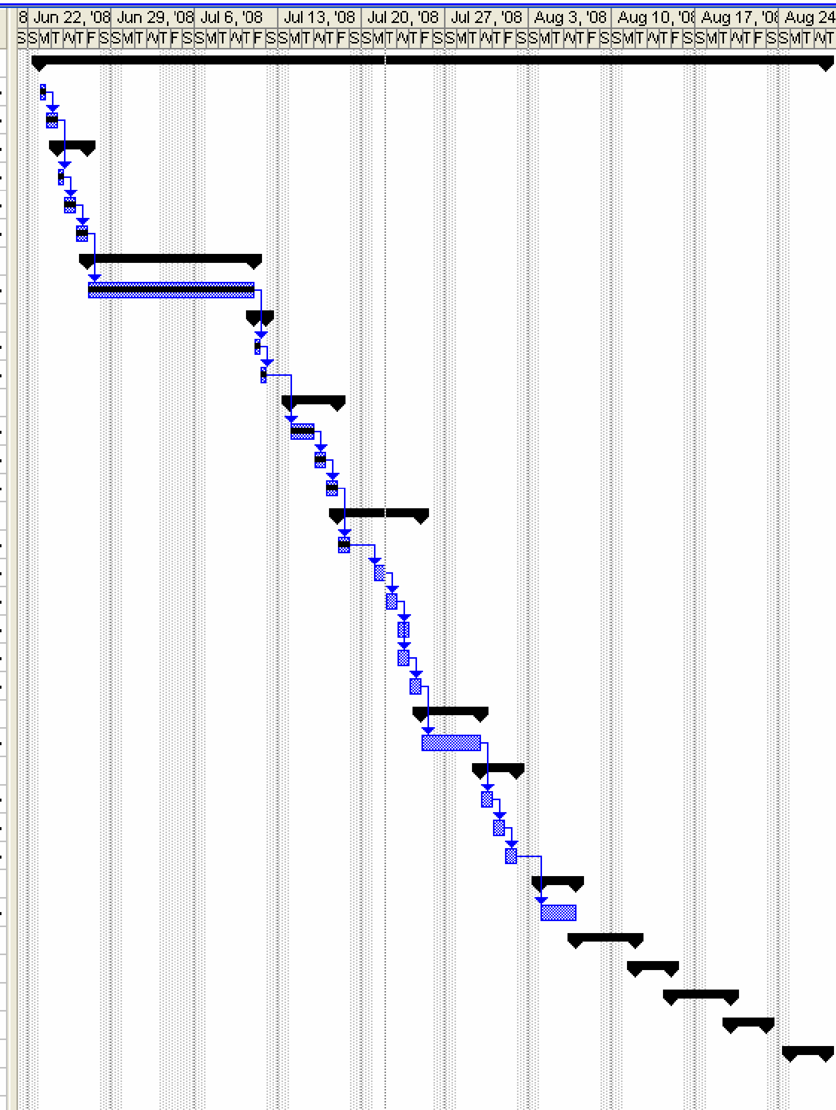
FS15149

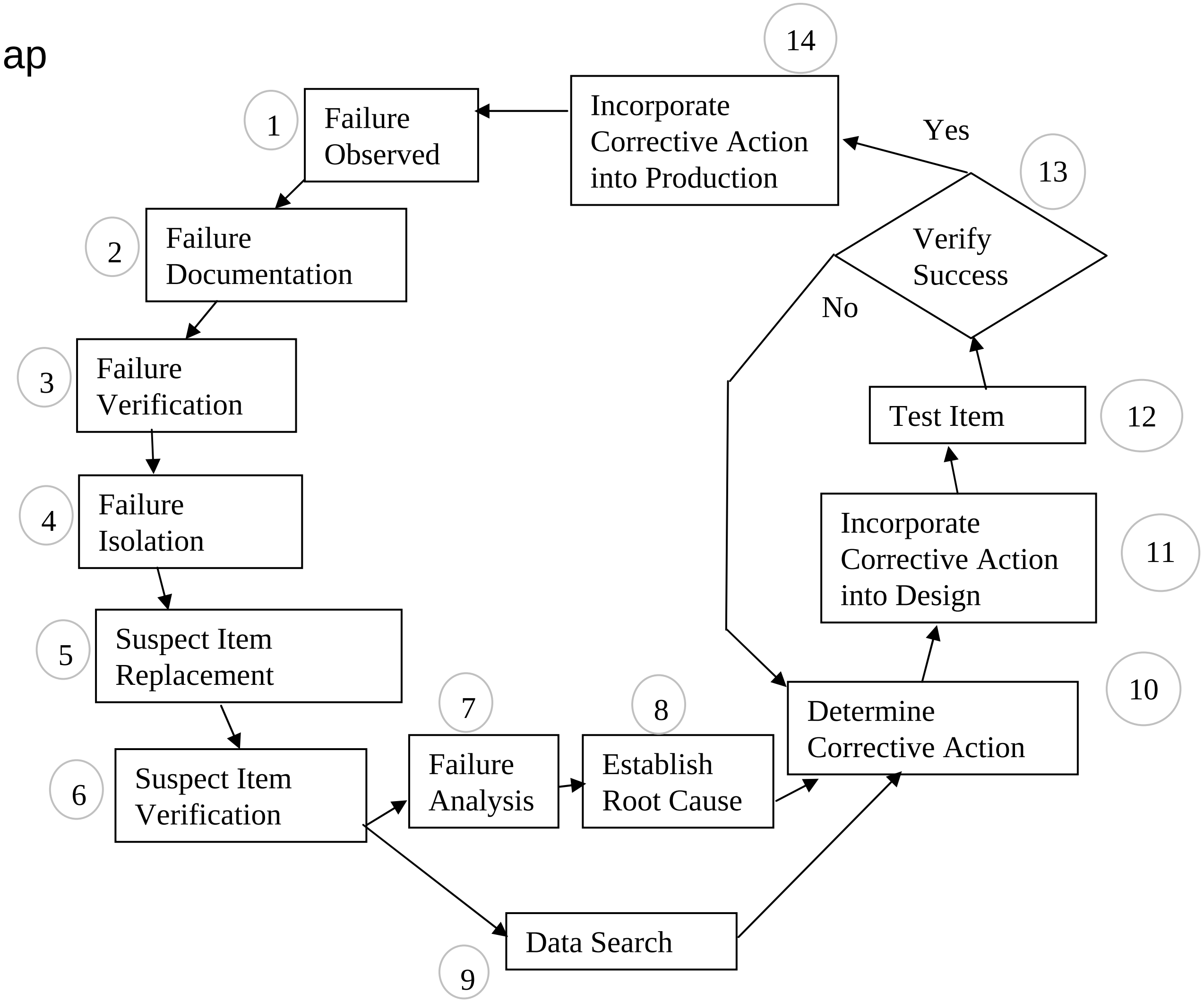
		Task Name	Duration	Start	Finish	% Complete
21		**Conduct Cannon Safety Test #2**	**46 days**	**Mon 6/23/08**	**Wed 8/27/08**	**38%**
22	✓	Move Gun to Barricade B1	0.5 days	Mon 6/23/08	Mon 6/23/08	100%
23	✓	Set Up for Cannon Safety Test	1 day	Mon 6/23/08	Tue 6/24/08	100%
24	✓	**Fire Baseline TID Group #1 (Rounds 1-30)**	**2.5 days**	**Tue 6/24/08**	**Thu 6/26/08**	**100%**
25	✓	Fire M1002 Baseline TID (Rounds 1-10)	0.5 days	Tue 6/24/08	Tue 6/24/08	100%
26	✓	Fire M829A3 Baseline TID (Rounds 11-20)	1 day	Wed 6/25/08	Wed 6/25/08	100%
27	✓	Fire M829A3 Baseline TID woithout Counterweights (Rour	1 day	Thu 6/26/08	Thu 6/26/08	100%
28	✓	**Expenditure Group #1 (Rounds 31-80)**	**8 days**	**Fri 6/27/08**	**Thu 7/10/08**	**100%**
29	✓	Fire 50 M829A2 @ 70F (Rounds 31-80)	8 days	Fri 6/27/08	Thu 7/10/08	100%
30	✓	**Fire Baseline TID Group #2 (Rounds 81-110)**	**1 day**	**Fri 7/11/08**	**Fri 7/11/08**	**100%**
31	✓	Fire M829A3 Baseline TID (Rounds 81-90)	0.5 days	Fri 7/11/08	Fri 7/11/08	100%
32	✓	Fire M829A3 Baseline TID without Counterweights (Rounc	0.5 days	Fri 7/11/08	Fri 7/11/08	100%
33	✓	**Prepare for BOP Testing**	**4 days**	**Mon 7/14/08**	**Thu 7/17/08**	**100%**
34	✓	Implace Stands	2 days	Mon 7/14/08	Tue 7/15/08	100%
35	✓	Install BOP Pressure Gages	1 day	Wed 7/16/08	Wed 7/16/08	100%
36	✓	Measure BOP Locations	1 day	Thu 7/17/08	Thu 7/17/08	100%
37		**Conduct BOP Testing (Rounds 111-140)**	**5 days**	**Fri 7/18/08**	**Thu 7/24/08**	**17%**
38	✓	Fire 5 M829A3 @ 70F (Rounds 101-105)	1 day	Fri 7/18/08	Fri 7/18/08	100%
39		Fire 5 M829A2 @ 70F (Rounds 106-110)	1 day	Mon 7/21/08	Mon 7/21/08	0%
40		Fire 5 M829A3 @ 120F Hot (Rounds 111-115)	1 day	Tue 7/22/08	Tue 7/22/08	0%
41		Fire 5 M829A2 @ 120F Hot (Rounds 116-120)	1 day	Wed 7/23/08	Wed 7/23/08	0%
42		Fire 5 M829A3 @ -25F Cold (Rounds 121-125)	1 day	Wed 7/23/08	Wed 7/23/08	0%
43		Fire 5 M829A2 @ -25F Cold (Rounds 126-130)	1 day	Thu 7/24/08	Thu 7/24/08	0%
44		**Expenditure Group #2 (Rounds 131-190)**	**3 days**	**Fri 7/25/08**	**Tue 7/29/08**	**0%**
45		Fire 50 M829A2 @ 70F (Rounds 131-190)	3 days	Fri 7/25/08	Tue 7/29/08	0%
46		**Fire Baseline TID Group #3 (Rounds 191-220)**	**3 days**	**Wed 7/30/08**	**Fri 8/1/08**	**0%**
47		Fire M1002 Baseline TID (Rounds 191-200)	1 day	Wed 7/30/08	Wed 7/30/08	0%
48		Fire M829A3 Baseline TID (Rounds 201-210)	1 day	Thu 7/31/08	Thu 7/31/08	0%
49		Fire M829A3 Baseline TID woithout Counterweights (Rour	1 day	Fri 8/1/08	Fri 8/1/08	0%
50		**Expenditure Group #3 (Rounds 221-270)**	**3 days**	**Mon 8/4/08**	**Wed 8/6/08**	**0%**
51		Fire 50 M829A2 @ 70F (Rounds 221-270)	3 days	Mon 8/4/08	Wed 8/6/08	0%
52		**Fire Baseline TID Group #4 (Rounds 271-300)**	**3 days**	**Thu 8/7/08**	**Mon 8/11/08**	**0%**
56		**Expenditure Group #4 (Rounds 301-370)**	**3 days**	**Tue 8/12/08**	**Thu 8/14/08**	**0%**
59		**Fire Baseline TID Group #5 (Rounds 371-400)**	**3 days**	**Fri 8/15/08**	**Tue 8/19/08**	**0%**
63		**Expenditure Group #5 (Rounds 401-470)**	**3 days**	**Wed 8/20/08**	**Fri 8/22/08**	**0%**
66		**Fire Baseline TID Group #6 (Rounds 471-500)**	**3 days**	**Mon 8/25/08**	**Wed 8/27/08**	**0%**
70						
71						



Test Supporting Elements Failure Reporting, Analysis, and Corrective Action System (FRACAS).

- Failure Reporting, Analysis, and Corrective Action System (FRACAS).
  - Provides a closed loop process to assess, review, correct problems
  - Failures are broken down to:
    - **Critical** – Involves a catastrophic or critical hazard related to health or safety of personnel; Categories I and II per MIL STD 882D/
    - **Major** – Involves a marginal hazard to safety of personnel (Category III per MIL STD 882D). Involves a critical safety hazard to the item/system under test (unplanned major system damage; Category II per MIL STD 882D), two or more repetitive minor incidents can also indicate a major failure.
    - **Minor** – Reflects an actual or incipient malfunction, defect, hazard, or negative finding that does not qualify as critical or major. Reports subtest results that reflect marginal performance.
    - **Informational** – Reports modification to the tested item, current condition of the tested item, test findings, subtest results, safety release information, or other types of information.
- Test Incident Report (TIR) generated during test events, a Corrective Action Report (CAR) is generated to document the failure, cause, and corrective action.
  - When the corrective action has been verified, the TIR can be closed

- Process Map


14
Incorporate Corrective Action into Production
1
Failure Observed
2
Failure Documentation
3
Failure Verification
4
Failure Isolation
5
Suspect Item Replacement
6
Suspect Item Verification
7
Failure Analysis
8
Establish Root Cause
9
Data Search
10
Determine Corrective Action
11
Incorporate Corrective Action into Design
12
Test Item
13
Verify Success
Yes
No

FMECA

Item/Functional Nomenclature	Function	Failure Mode	Failure Mode Cause	Local Effect	Next Higher Effect	System Effect	Design Mitigation	Failure Detection Mode	SEV	OCC	DET
Housing	Platform for mechanisms which enable breech block to be driven open and closed via actuation of the breech housing assembly.	Fractures	Vibration, fatigue, shock load; bumper stop failure; galvanic corrosion	Loss of breech housing function	Breech will not close/open	Unable to fire; debris in the turret	FEA; ATD live fire testing; based on previous (LW120) systems	Visual inspection; detection via diagnostic sensor(s)	5	2	3
		Distortion	Firing loads, breech block impact, thermal expansion	Component misalignment	Breech may not open/close	May not be able to fire/load/unload		Visual inspection; detection via diagnostic sensor(s)	4	2	3
		Fastener(s) fail	High shear loads; loosening	Component misalignment	Breech may not open/close	May not be able to fire/load/unload; debris in the turret		Visual inspection; detection via diagnostic sensor(s)	4	3	4
		Bearing failure	Fatigue, misalignment	Bearings wear unevenly	Increased breech cycle times and motor torque	Reduced system functionality; electric actuation in jeopardy		Visual inspection; detection via diagnostic sensor(s); resolver cycle times	4	2	3

- Item/Functional Nomenclature
- Function – short description of item function
- Failure Mode – primary item failure means
- Failure Mode Causes – underlying causes for the primary failure modes
- Local Effect – failure effects on the item level
- Next Higher Effect – failure effects on the next level up assembly/subassembly
- System Effect – failure effects on the system level
- Design Mitigation – means to minimize the failure mode and causes
- SEV – hazard severity level
  - 5 Catastrophic
  - 4 Critical
  - 3 Marginal
  - 2 Negligible
  - 1 Minor
- OCC – hazard probability of occurrence
  - 5 Frequent
  - 4 Probable
  - 3 Occasional
  - 2 Remote
  - 1 Improbable
- DET – probability of detection during design
  - 1 Very High (> 99%)
  - 2 High (90-99%)
  - 3 Moderate (75-89%)
  - 4 Low (60-74%)
  - 5 Very Low (< 60%)
- RPN – risk priority number; “The higher the resulting index the more urgent the need to find a solution”

$$RPN = SEV \times OCC \times DET$$

Test Supporting Elements
FMECA

- FMECA provides (from a test standpoint):
  - Guideline on instrumentation and test focus areas
  - Clues on failure modes and approaches

Certification

- Upon completion of testing:
  - All test reports reviewed for safety related incidents & concerns
  - HHAR is completed (All safety related issues must be mitigated)
  - Request is sent to DTC to independantly assess and verify all test reports
  - DTC issues Safety Certification Finding
  - Review Board (Defense Acquisition Board) accepts or rejects findings and “Type Classifies” the product (no longer ‘experimental’)
  - Product is now considered ‘fielded’ and can be used by soldiers

120 MM XM360 Firing off XM1202 Mounted Combat System Turret – Aberdeen Test Center – January 2009.